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MACI JOURNAL OF MULTIDISCIPLINARY ADAPTIVE CLIMATE INSIGHTS

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Our journal strives to contribute essential research findings to the international community, aiding researchers, scientists, institutions, and societies in staying abreast of new developments in theory and applications. We welcome experimental, computational, and theoretical studies that enrich the understanding of climate-related challenges.

Focal areas of interest include, but are not limited to, climate adaptation, mitigation strategies, interdisciplinary studies, climate trends, climate data analysis, climate modeling, climate economics, and the impact of climate change on agriculture, water resources, health, and the environment. We emphasize the integration of climate science into various fields and the collaboration needed to address the complex challenges posed by climate change.

Sustainable development is at the core of our mission. We believe in meeting human development goals while preserving the capacity of natural systems to provide essential resources and ecosystem services. Case studies exploring the intersection of sustainable development and climate challenges are particularly encouraged.

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Tradition Meets Innovation: Preferences for Climate Strategies Among Cocoa Farmers in Obuasi Municipality, Ghana

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Abstract:

The purpose of the study was to compare the traditional and modern adaptation strategies employed by cocoa farmers in response to climate variability in the Obuasi Municipality. A qualitative approach was employed, involving in-depth interviews using a purposive sampling technique to select twenty (20) cocoa farmers and five (5) key informants. The findings revealed that farmers use a blend of traditional strategies, such as shade management, crop diversification, and local weather indicators, as well as modern strategies, including pruning, artificial irrigation, and agrochemical applications. While modern methods were often seen as more effective, traditional methods remained widely preferred for their affordability, accessibility, and cultural embeddedness. Factors influencing the choice of strategies included gender, Education, financial capacity, land ownership, and access to extension services. Notably, the study found that combining both traditional and modern methods provided the most promising adaptation pathway, especially when supported by training, government interventions, and community-based platforms. The study has implications for agricultural extension services, policymakers, and NGOs by demonstrating the need to promote inclusive, participatory, and locally adaptable interventions. Strengthening locally grounded yet scientifically informed adaptation systems can enhance cocoa sector resilience to climate change while safeguarding cultural knowledge and farmer agency.

Keywords: Adaptation strategies, Climate change, Innovation, Preferences, Traditional practices.

1. Introduction

Climate change has emerged as one of the most pressing challenges to agricultural production worldwide, exerting significant pressure on both crop yields and rural livelihoods. In the tropics, perennial cash crops such as cocoa (*Theobroma cacao* L.) are particularly vulnerable due to their sensitivity to temperature fluctuations, rainfall variability, and pest infestations (Ameyaw et al., 2018; Tham-Agyekum et al., 2024). In recent decades, cocoa-growing regions have experienced increasingly unpredictable rainfall patterns, rising average temperatures, and greater incidences of diseases and pests. These climatic shifts threaten not only the economic viability of cocoa production but also the sustainability of rural economies that depend heavily on it. Ghana, the world's second-largest cocoa producer, has not been spared these challenges. The cocoa sector contributes significantly to Ghana's GDP, foreign exchange earnings, and employment, yet it faces mounting risks from climate-induced stresses (Attiogbé et al., 2024).

Ghanaian cocoa farmers have relied on a range of traditional, locally derived adaptation strategies to mitigate environmental stresses (Adu-Boahen, 2023). Such practices include shade management, intercropping with food crops, mulching, and the application of organic fertilisers. These approaches are deeply embedded in local knowledge systems, passed down through generations, and adapted to the ecological and socio-economic contexts of rural communities (Denkyirah et al., 2017). In recent years, however, the increasing availability of modern agricultural technologies and the introduction of climate-smart agricultural policies have expanded the portfolio of potential adaptation strategies available to farmers. These modern approaches include the adoption of irrigation systems, improved and drought-tolerant cocoa varieties, mobile-based weather advisory services, and precision agriculture techniques (Tham-Agyekum et al., 2024; Apuri et al., 2025).

Globally, empirical evidence reveals a diverse spectrum of adaptation preferences among farmers, shaped by a complex interplay of socio-economic, cultural, institutional, and environmental factors. For instance, in Indonesia, farmers with greater access to credit and agricultural extension services have been found to adopt modern strategies more readily than those without such support (Abdulai, 2018). In Brazil, however, traditional adaptation methods such as agroforestry have been shown to outperform modern irrigation in conserving soil moisture and reducing crop heat stress (Schroth et al., 2016). In Nigeria, despite productivity gains linked to modern practices, many cocoa farmers continue to prefer traditional methods due to their affordability and alignment with cultural values (Famakinwa et al., 2023; Obaniyi et al., 2019). In Cameroon, a hybrid approach that combines traditional measures like shade tree retention with modern irrigation has been reported to enhance resilience to climatic extremes (Cédric et al., 2025).

In Ghana, adaptation choices are also influenced by farmers' socio-demographic characteristics, access to resources, and perceptions of risk. Adu-Boahen (2023) found that older cocoa farmers in the Ashanti Region tended to favour traditional strategies, often due to scepticism about modern technologies, while younger farmers demonstrated greater openness to innovation. In Western Ghana, although modern strategies such as irrigation and improved varieties have been shown to improve yields, their adoption remains constrained by poor access to finance, inadequate extension services, and knowledge gaps (Batung, 2021; Mwinkom et al., 2023).

Over the past decade, a gradual evolution in cocoa farmers' adaptive responses to climate change has been observed. Initially, adaptation was dominated by low-cost, locally accessible practices such as mixed cropping, crop rotation, and agroforestry. However, increasing emphasis has been placed on climate-smart technologies, including advanced irrigation systems, mobile weather applications, and genetically improved, drought-tolerant cocoa varieties (Denkyirah et al., 2017). Despite the benefits, uptake of these modern innovations remains limited due to their high costs, lack of technical training, and the enduring cultural significance of traditional methods (Adu-Boahen, 2023).

The institutional context further shapes adaptation preferences. The Ghana Cocoa Board (COCOBOD), the statutory body overseeing cocoa production, marketing, and pricing, plays a pivotal role in introducing new technologies and inputs to farmers (Ollendorf, 2024). While government programmes such as the Cocoa Rehabilitation Programme and Climate-Smart Cocoa projects have introduced improved seedlings, drip irrigation, and agroforestry

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packages, their effectiveness is contingent upon farmer acceptance and sustained use. At the same time, structural challenges—such as deforestation, soil degradation, and competition for land from mining—compound climate-related risks, especially in districts like Obuasi (Owusu, 2022).

The Obuasi Municipality presents a particularly interesting case for examining adaptation preferences due to its unique socio-ecological context. While sharing many climatic challenges with other cocoa-growing regions, Obuasi also faces land degradation from small-scale mining, competition for arable land, and specific microclimatic conditions that influence farming decisions (Tham-Agyekum et al., 2023). Yet, many Ghana-based adaptation studies have focused on the Ashanti and Western cocoa regions (Ameyaw et al., 2018), leaving areas such as Obuasi underrepresented in scholarly literature. This geographic gap limits the applicability of policy recommendations to all cocoa-growing contexts.

Existing studies on cocoa adaptation have provided valuable insights into the types of strategies farmers employ (Bunn et al., 2019; Anning et al, 2022), as well as the socio-economic and institutional factors influencing adoption (Afriyie-Kraft et al., 2020; Obaniyi et al., 2019; Schroth et al., 2016). However, much of the literature relies on either broad-scale quantitative surveys that may overlook nuanced individual experiences or qualitative approaches that lack representativeness (Guodaar et al., 2021). Moreover, while the efficacy of both traditional and modern adaptation measures has been documented, there is less understanding of farmers' explicit preferences and the motivations underpinning them. This knowledge gap is critical, as adaptation preferences shape the likelihood of sustained adoption and the eventual success of policy interventions.

An important unresolved issue in climate adaptation discourse is the persistent disconnect between top-down policy advocacy for modern, climate-smart practices and farmers' real-world decisions. Substantial investments have been made in promoting modern adaptation technologies in Ghana, yet adoption rates remain low (Owusu, 2022). Understanding why farmers continue to rely on traditional methods, despite the availability of scientifically validated alternatives, can help bridge this gap. This is not merely a matter of technical efficiency; it also touches on the socio-cultural legitimacy of agricultural innovations and the perceived trade-offs between economic risk, cultural continuity, and environmental sustainability.

Furthermore, debates persist regarding the role of traditional ecological knowledge in the context of rapidly changing climatic conditions. Some scholars argue that traditional practices are inherently adaptive and provide resilience against environmental shocks, while others contend that these methods may be insufficient in addressing the unprecedented challenges posed by climate change (Apraku et al., 2021; Bekuma et al, 2023). A growing body of literature suggests that integrated approaches blending traditional and modern practices offer the most promising pathway to sustainable adaptation (Cédric et al., 2025). Yet, the balance between these two modes of adaptation remains largely underexplored in empirical research, particularly in Ghana's under-studied cocoa districts.

This study addresses these gaps by examining cocoa farmers' preferences for traditional and modern climate adaptation strategies in the Obuasi Municipality. Using a qualitative research design, it captures the lived experiences, perceptions, and decision-making processes of farmers to generate a nuanced understanding of adaptation preferences. By focusing on an under-researched geographic area, the study contributes to a more complete national picture of cocoa adaptation strategies. Moreover, it provides actionable insights for policymakers, development agencies, and extension services seeking to design context-appropriate interventions that align with farmers' values, resources, and long-term sustainability goals.

The main objective of the study was to examine cocoa farmers' preferences for traditional and modern climate adaptation strategies in Obuasi municipality. The specific objectives of the study were: to identify the traditional and modern climate adaptation strategies used by cocoa farmers in Obuasi Municipality, to examine cocoa farmers' perceptions of traditional and modern adaptation strategies, to assess the extent to which cocoa farmers prefer traditional adaptation strategies and modern strategies, to analyse the factors influencing cocoa farmers' preferences for traditional and modern adaptation strategies, to evaluate the perceived effectiveness of traditional and modern adaptation strategies.

2. Research methodology

2.1. Research design

This study adopted a qualitative research design, which prioritises depth of understanding, exploration of meanings, and the contextual interpretation of lived experiences rather than statistical generalisation (Pervin & Mokhtar, 2022). The study employed an explanatory and descriptive research approach because climate adaptation strategies among cocoa farmers have not been extensively studied in the Obuasi Municipality. The descriptive aspect helps to systematically document and analyse farmers' preferences for traditional and modern adaptation strategies, their perceptions, and the factors influencing their choices (Fuyane, 2021). A qualitative methodology was appropriate for this research because it allows an in-depth understanding of farmers' perspectives, beliefs, and motivations regarding climate adaptation. Unlike quantitative studies, which rely on numerical data, qualitative research provides richer insights into how farmers make decisions and why they prefer certain strategies over others (Peterson, 2019).

2.2. Study area

The study was conducted in the Obuasi municipality in the Ashanti region of Ghana. Approximately 19% of the working population in the Obuasi Municipality is engaged in mining, though agriculture remains the dominant employment sector with about 62% of residents involved in it (Osman et al., 2021). The municipality's climate is classified as tropical rainforest, characterized by two main rainy seasons and a dry season, which makes it highly susceptible to climate variability. Figure 1 shows a map of the Obuasi Municipal Area.

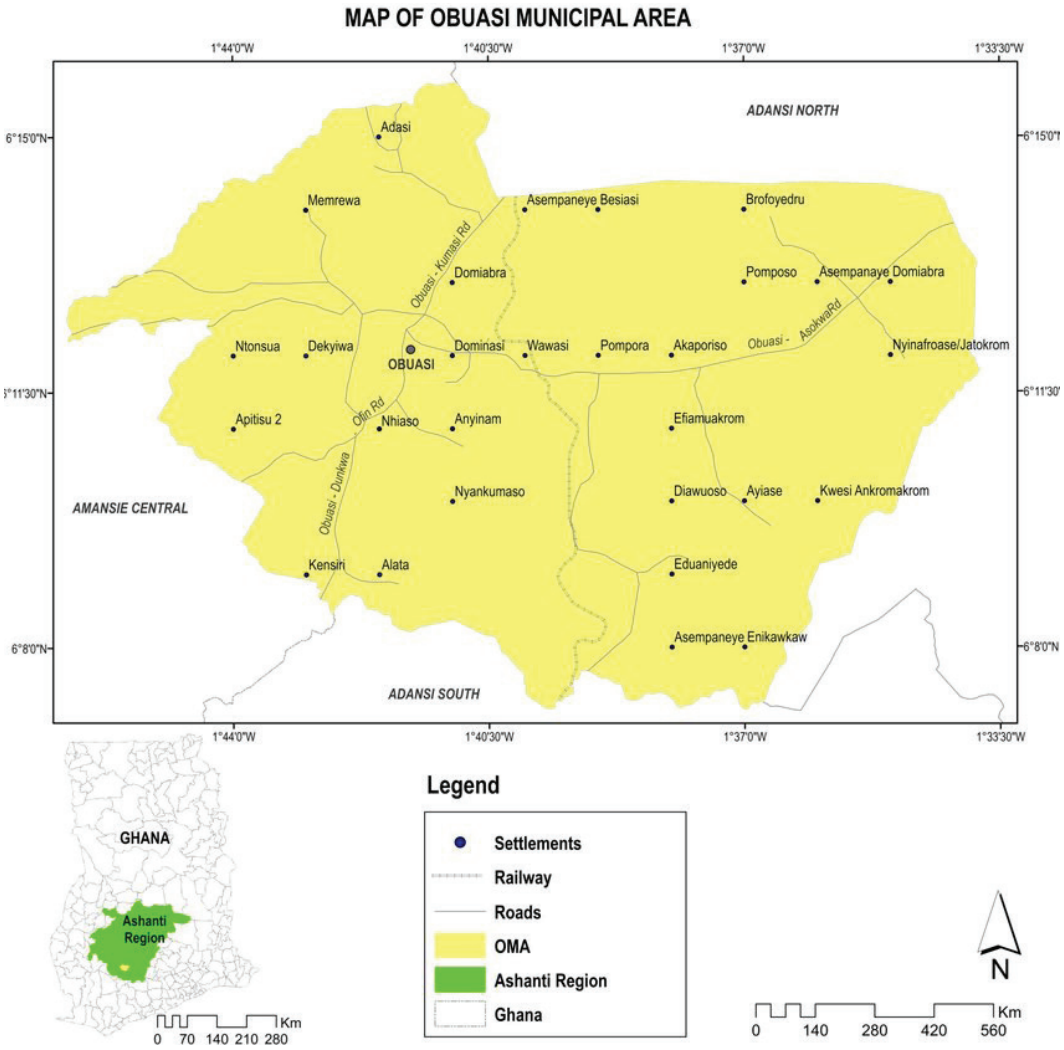

Figure 1: Map of Obuasi Municipal

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2.3. Sampling

Purposive sampling was used to select participants with relevant knowledge and experience. Inclusion criteria required farmers to have at least five years of cocoa farming experience and to actively use either traditional or modern adaptation strategies (Kubiciel-Lodzińska, 2021). In total, 25 respondents, including 20 farmers and five (5) key informants (agricultural extension officers and climate adaptation specialists), were interviewed. The sample size was guided by the principle of data saturation, which was reached when no new themes emerged after repeated interviews (Cassell & Bishop, 2019; van Leeuwen et al., 2020; Tavory, 2020).

While the sample may appear small when compared to quantitative studies, such sizes are well established in qualitative research traditions. The study's aim was not to provide statistically representative conclusions, but rather to uncover diverse perspectives, preferences, and influencing factors shaping adaptation strategies. To strengthen the credibility and trustworthiness of the findings, the study applied methodological strategies such as triangulation of data sources (farmers and key informants), member checking, and thematic coding consistency. These steps enhanced the reliability of the data, ensuring that the conclusions drawn are robust and grounded in participants' lived experiences.

2.4. Data collection and analysis

Data were collected through semi-structured interviews, key informant interviews, and observations. The interview guides explored farmers' adaptation practices, perceptions, and influencing factors, while the key informant guide focused on policy implementation and institutional support. Interviews lasted 30 45 minutes, were conducted in English and Twi, and were audio-recorded with consent. A short pilot test was conducted to refine the instruments. All interviews and discussions were recorded with participant consent. Where writing recoding was difficult, the audios were later transcribed for thematic analysis. The use of multiple instruments ensured data triangulation to enhance the reliability and validity of the findings (Santos et al., 2020). Coding was conducted manually, guided by the study objectives. Emerging codes were grouped into broader themes related to adaptation strategies, perceptions, influencing factors, and effectiveness. Themes were reviewed for consistency, and illustrative quotes were used to represent participant voices. Credibility was enhanced through triangulation of farmer and key informant perspectives and member checking with a subset of participants.

Table 1: Interview themes and number of questions

Theme/Domain	Focus of Questions	No. of Questions (Farmers)	No. of Questions (Key Informants)
Background Information	Age, gender, Education, household composition, years in cocoa farming/professional role	5	3
Perceptions of Climate Change	Awareness of changing rainfall/temperature patterns, observed impacts on cocoa production, and gendered impacts	6	4
Traditional Adaptation Strategies	Shade tree planting, mulching, intercropping, indigenous weather signs, and cultural knowledge transfer	5	3
Modern Adaptation Strategies	Hybrid seedlings, irrigation, pesticides/fungicides, agroforestry, weather-based planning	6	5
Preferences	Reasons for choosing traditional vs modern, generational differences, affordability, and cultural attachment	4	3
Influencing Factors	Economic, social, institutional, gender, Education, extension services	5	5
Perceived Effectiveness	Strengths and weaknesses of traditional, modern, and integrated practices; conditions of effectiveness	5	5
Policy and Institutional Support	Role of COCOBOD, CHED, NGOs, government policies, and challenges in programme delivery	3	6
Future Outlook	Farmers' expectations about climate trends and adaptation pathways	2	2

Table 1 summarises the themes and the number of questions used in the semi-structured interviews. Farmer interviews comprised 41 questions across nine themes, while key informant interviews included 36 questions tailored to policy and institutional dimensions. The thematic focus on both traditional and modern adaptation strategies, as well as perceptions, preferences, and influencing factors, ensured that data collection was aligned with the study objectives.

3. Results and discussion

Table 2: Demographic table for participants

Category	Farmers (n = 20)	Key Informants (n = 5)
Gender	Male: 14 (70%) Female: 6 (30%)	Male: 4 (80%) Female: 1 (20%)
Age (years)	30–39: 3(15%) 40–49: 7 (35%) 50–59: 6 (30%) 60+: 4 (20%)	30–39: 2 (40%) 40–49: 3 (60%)
Education Level	No formal education: 4 (20%) Primary/JHS: 8 (40%) SHS: 5 (25%) Tertiary: 3 (15%)	SHS: 1 (20%) Tertiary: 4 (80%)
Farming/Professional Experience	5–9 years: 6 (30%) 10–19 years: 9 (45%) 20+ years: 5 (25%)	5–14 years: 3 (60%) 15+ years: 2 (40%)

Source: Field Data, 2025

Table 2 presents the demographic profile of the study participants. Among the 20 cocoa farmers interviewed, the majority were male (70%) and aged between 40 and 59 years (65%). Education levels varied, with 20% having no formal education, while 15% had attained tertiary Education. Farming experience ranged from 5 to over 20 years. The five key informants, drawn from extension services and climate adaptation programmes, were predominantly male (80%) and had substantial professional experience, with most (60%) having worked between 5 and 14 years.

3.1. Identify traditional and modern climate adaptation strategies

Table 3: Adoption of traditional vs. Modern adaptation strategies (Farmers, n = 20)

Traditional Strategies	Frequency	Percentage (%)	Modern Strategies	Frequency	Percentage (%)
Planting shade trees	15	75%	Improved hybrid seedlings	8	40%
Timing activities by indigenous weather signs	12	60%	Artificial irrigation (pumps, watering)	4	20%
Mulching with local materials	10	50%	Agrochemical use (fungicides, insecticides)	9	45%
Intercropping (cassava, plantain, yam with cocoa)	14	70%	Agroforestry with certified shade trees	6	30%
Burning grass before planting (declining)	5	25%	Weather-based planning using forecasts	7	35%

Source: Field Data, 2025

The majority of farmers reported using traditional strategies, particularly shade tree planting (75%) and intercropping (70%). Reliance on indigenous weather signs (60%) and mulching (50%) also remained widespread. This shows that the common traditional strategies used by farmers are the planting of shade trees, timing farm activities based on indigenous weather indicators,

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mulching with locally available plant materials, and intercropping with food crops to conserve soil moisture and diversify income. A middle-aged male farmer explained, *"My father always told me to watch the wind and the sky before clearing land. Even now, I don't start planting until the old signs tell me rain will come."* Similarly, an experienced female farmer shared how family knowledge influences her practice: *"I learnt from my grandmother that planting plantain trees near young cocoa helps them to survive long dry spells. I still do that today."* These accounts echo findings from Antwi-Agyei et al. (2023), who highlight the continued relevance of traditional ecological knowledge in Ghana's smallholder adaptation systems. Some older techniques have even become counterproductive. Another farmer reflected: *"We used to burn grass before planting to add ash to the soil, but now the sun is too hot, it just dries everything up faster."* Codjoe et al. (2013) agree with this assertion and noted that rising temperatures and unpredictable rainfall have rendered some traditional land preparation methods less effective.

By contrast, fewer farmers had adopted modern strategies such as irrigation (20%) or certified shade trees (30%). Agrochemical use (45%) and hybrid seedlings (40%) were more common, often linked to NGO or extension support. The participants reported some awareness of modern adaptation strategies, primarily introduced through agricultural extension services, non-governmental organisations (NGOs), or cocoa-related development projects. A male farmer described his introduction to improved seedlings: *"An extension officer gave me a new variety of cocoa that can survive the dry season better and produce more yield. I planted them two years ago."* Another male farmer noted: *"We were trained to use improved seedlings and fertiliser at certain times to reduce losses from drought."* Such findings are similar to those of Danso-Abbeam et al. (2019), who argued that modern adaptation technologies are increasingly disseminated via Ghana's extension systems, particularly in cocoa-growing regions. Adoption levels varied, in that some farmers incorporated agroforestry practices by planting certified shade trees such as *Terminalia superba* and *Milicia excelsa* alongside cocoa. A farmer remarked, *"We were told to space out the cocoa and plant shade trees to reduce heat stress. It helps, especially during harmattan."* Others also adopted small-scale irrigation. As a farmer explained, *"I have a small water pump now. It's not enough, but during dry spells, I use it on the younger trees. It makes a difference."* Support for these strategies often came from the Cocoa Health and Extension Division (Ghana Cocoa Board) and NGOs such as Solidaridad. Confidence in using modern strategies was mixed. Younger and more educated farmers tended to be more comfortable with technological methods, whereas older or less-educated farmers felt less confident. As one male farmer said, *"I know how to use some chemicals, but with irrigation or machines, I get confused. No one teaches us properly."* This confirms findings of studies such as Srivastava et al. (2025) and Jiri et al. (2016), who found that Education and quality extension support increase farmers' confidence in adopting modern adaptation measures.

3.2. Perceptions of climate change

Table 4: Perceptions of climate change (Farmers, n = 20)

Perception of Change	Frequency	Percentage (%)
Rainfall increasingly erratic	20	100%
Longer dry spells	18	90%
Rising temperatures	15	75%
Shift in the onset of the rainy season	17	85%
More pest/disease outbreaks	14	70%
Declining yields	16	80%

Source: Field Data, 2025

All farmers unanimously perceived rainfall as increasingly erratic, while 90% reported longer dry spells. A large proportion also noted a shift in the onset of the rainy season (85%), rising temperatures (75%), and declining yields (80%). Over two-thirds (70%) associated these climatic changes with higher pest and disease incidence, consistent with scientific studies linking cocoa vulnerability to climatic variability. There was unanimous agreement that rainfall has become increasingly erratic, dry seasons are longer, temperatures are rising, and the onset of the rainy season has shifted unpredictably. A cocoa farmer with over three decades of experience, recalled: *"The rains no longer come as they used to. We used to expect them in March and September, but now it is unpredictable. This confuses our planting and spraying schedules."* The findings of Asante and Amuakwa-Mensah (2015) and Antwi-Agyei et al. (2021) agree that climate change has altered rainfall distribution

in Ghana, thereby affecting the reliability of rain-fed agriculture. A 45-year-old farmer managing a 3-acre cocoa farm, lamented the intensification of dry spells: *"The sun is so harsh now. My cocoa trees look like they are burning, especially during the harmattan. We didn't experience this kind of heat before."* According to Schroth et al. (2016), temperatures exceeding 26°C can negatively affect cocoa tree flowering and pod development, leading to yield reductions.

Several farmers reported that these climatic changes have led to a noticeable decline in yields, heightened pest and disease pressure, and increased production costs. A middle-aged farmer from the northern outskirts of the municipality, described the growing challenge of pest control: *"I now spend more on pesticides because the black pod disease is getting worse with all this rain and humidity."* Such accounts reinforce an earlier study that have linked climatic variability with higher incidence of cocoa pests and diseases (Bunn et al., 2019).

The economic consequences were also a recurring theme. One farmer reflected on the financial strain: *"We don't earn like before. Some of us are thinking of leaving cocoa farming altogether."* Declining incomes not only compromise household welfare but also undermine farmers' ability to reinvest in their farms, perpetuating a cycle of vulnerability. A notable observation from the interviews was that most farmers saw these climate changes as permanent rather than temporary. A farmer with intergenerational farming knowledge asserted, *"This is not something that will go away. We must find a way to live with it. Our fathers did not face this."* Deressa et al. (2009) also noted that farmers' recognition of climate change as a long-term phenomenon often motivates proactive adaptation.

The gendered nature of these impacts was also evident in the narratives of female farmers. Another female farmer highlighted the increased domestic burden: *"We women now walk longer distances to fetch water for our homes and farms. The streams are drying up."* Doss (2018) noted that climate change frequently deepens existing gender inequalities, particularly in rural contexts where women rely heavily on natural resources. Climate stressors were also found to be reshaping household roles and responsibilities. One male farmer observed, *"I now have to help more at home because my wife is also stressed from farm work. The weather has made everything harder."* Carr and Thompson (2014) agree that climate-related pressures can lead to shifts in household labour distribution, often increasing the workload for both men and women.

The key informants provided broader contextual insights. They all reported noticeable shifts in rainfall patterns, with delayed onset and shorter but more intense rains. One extension officer with over a decade of experience observed: *"We no longer see the predictable March–July rains. Sometimes, the rains delay until June, and even when they come, they are too intense and short-lived."* This is supported by Kimengsi and Tosam (2013), who identified erratic rainfall and temperature extremes as major threats to Ghana's cocoa production zones. According to the climate adaptation specialist, prolonged dry spells have reduced pod development and increased pest pressure, particularly capsid infestations, while excessive rains have heightened the prevalence of black pod disease. She also noted the spread of the swollen shoot virus due to farmers unknowingly exchanging infected planting material. Gendered impacts were also highlighted. A cocoa extension officer explained that women, who often manage smaller plots and rely more on off-farm income, are disproportionately affected by delayed rains: *"Men can still hire labour and irrigate, but many women can't afford that."* This aligns with studies by Kuhn et al. (2023) and Kissi and Herzig (2024), who documented gendered vulnerabilities in African agriculture. The consensus among informants was that farmers face multiple climate-induced challenges, including drought, excessive rainfall, interseasonal dry spells, windstorms, and pest and disease outbreaks, that require both traditional and modern strategies.

3.3. Preferences

Table 5: Preferences for adaptation strategies (Farmers, n = 20)

Preference	Frequency	Percentage (%)
Traditional methods	10	50%
Modern methods	6	30%
Hybrid (mix of both)	4	20%

Source: Field Data, 2025

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About 50% of the farmers preferred traditional strategies, citing affordability, accessibility, and cultural familiarity. Modern methods appealed to 30% of respondents, especially younger and more educated farmers, who valued higher yields and resilience. A smaller group (20%) advocated hybrid approaches, combining mulching and intercropping with fertiliser use or hybrid seedlings. The data show that preferences among the cocoa farmers varied considerably, though a notable leaning towards traditional methods emerged in several accounts. Many respondents expressed a strong attachment to the practices they had grown up with, citing their affordability, accessibility, and cultural familiarity. For instance, a young female farmer with five years of experience explained: "*The old ways are what I grew up with; mulching, intercropping, and observing the skies. They are natural, safe, and I don't have to depend on anyone.*" Similarly, a farmer with nearly two decades of cocoa farming experience remarked, "*I still trust the traditional methods more. The new ones are good, but they cost money, and sometimes they don't work as well because the weather keeps changing.*" Such sentiments align with earlier studies by Fosu-Mensah et al. (2012) and Asante and Amuakwa-Mensah (2015), which found that although modern climate adaptation strategies are becoming increasingly available in Ghana. They claimed that many farmers still rely heavily on traditional practices because of their familiarity, affordability, and locally proven effectiveness.

Other farmers, however, expressed a clear preference for modern methods, particularly those offering higher yields and better resilience during extreme weather events. A younger farmer, for example, explained: "*I prefer the new ways, especially the improved seedlings and irrigation. They are more reliable during extreme weather.*" The perceived attractiveness of one method over another often depended on factors such as cost, availability, perceived effectiveness, and ease of use. As one middle-aged farmer noted, "*Modern methods are good, but they are expensive and hard to get. Traditional methods like planting yams or cassava beside cocoa still help the soil and prevent loss.*" In contrast, another farmer argued that modern methods provided faster returns: "*With improved seedlings, I saw more pods in just three years. I never got that from the old ones.*" These views are consistent with Nelson and Agbey (2005), who contend that economic factors and expected yields heavily influence farmers' choices, particularly among younger or more market-oriented producers.

Shifts in preferences over time were also evident. For example, one experienced farmer recounted: "*I used to rely only on traditional ways, but after the floods in 2021, I started using fertilizer and planting hybrid cocoa. I can't depend on the weather anymore.*" This shows how extreme weather events and changing climatic patterns are prompting farmers to re-evaluate their adaptation strategies (Antwi-Agyei et al., 2014). Nonetheless, some participants remained loyal to traditional approaches despite the changing climate. As one young female farmer explained, "*The changes are scary, but I still use what I know. It's safer and doesn't spoil the soil.*"

A recurring theme across interviews was that older farmers tended to favour traditional methods, whereas younger or more educated farmers leaned towards modern strategies. One farmer observed: "*Most of the older folks in the village still use traditional ways. They say it's how they survived droughts before. But the youth want to try the new ones.*" Deressa et al. (2011) also argued that age and Education significantly influence openness to adopting new agricultural technologies.

Despite these differences, there was a widespread recognition of the potential benefits of combining both traditional and modern approaches. Many farmers viewed integrated practices as a way to enhance resilience while maintaining soil health and cultural practices. One experienced female farmer explained: "*I think using both is better. The traditional methods help preserve the land, and the modern ones increase yield.*" Another farmer added, "*We don't have to choose one. Even the extension officers say we should mix them.*" This perspective reflects the "hybrid knowledge systems" concept described by Nyantakyi-Frimpong and Bezner-Kerr (2015), which emphasizes the integration of indigenous knowledge and scientific innovation as a robust adaptation strategy.

3.4. Influencing factors

Table 6: Factors influencing adoption (Farmers, n = 20)

Influencing Factor	Frequency	Percentage (%)
Financial capacity/cost	14	70%
Institutional support (extension, NGOs, cooperatives)	9	45%
Social/gender roles	6	30%
Education/literacy	7	35%
Peer/family influence	5	25%

Source: Field Data, 2025

Economic constraints were the most cited barrier, with 70% of farmers emphasising limited financial resources. Institutional support was mentioned by 45%, often tied to access to seedlings or training. Education influenced 35% of farmers, while 30% highlighted gender roles, noting that women faced additional barriers due to land and labour access. Peer and family influence was less commonly cited (25%), though it remained important in sustaining traditional practices. As one young farmer explained, *"Modern methods are good, but they need money, and not all of us can afford them."* This is consistent with Asante and Amuakwa-Mensah (2015), who highlighted that financial constraints significantly hinder rural farmers' ability to adopt innovative practices. The affordability of traditional methods, such as mulching or intercropping, often made them the default choice for farmers with limited capital.

Institutional support also played a substantial role in shaping adoption patterns. Access to cooperatives, NGOs, and agricultural information through media platforms was found to be a strong enabling factor. For instance, one farmer reported that listening to farming programmes on Adom FM and Ayekoo on UTV introduced him to shade management techniques, which he subsequently adopted. Another respondent credited his membership in a local cocoa farmers' association for providing him with training and access to improved seedlings. These experiences reflect the observations of Antwi-Agyei et al. (2014), who emphasized that extension services, farmer organizations, and other institutional networks are pivotal in facilitating the uptake of climate-resilient agricultural strategies.

Social dynamics, including gender roles and marital status, further shaped farmers' decisions. Some women faced barriers to adoption due to limited access to labour or land. For example, a widowed farmer explained that her inability to mobilize the labour needed for certain modern strategies made them impractical for her. In contrast, another respondent shared that her supportive husband enabled her to jointly experiment with both traditional and modern methods. Such gendered differences resonate with the findings of Jost et al. (2016), who noted that women's agricultural choices are often constrained by cultural norms, limited financial autonomy, and reduced access to productive resources.

Educational attainment was another significant determinant. Farmers with higher levels of formal Education or functional literacy expressed greater confidence in understanding and applying modern adaptation practices. They reported that their ability to read and interpret training manuals and extension materials made them more willing to try modern techniques. One participant stated, *"Because I can read and understand the manuals they give us, I try the modern methods."* This finding aligns with Jalloh et al. (2013), who observed that Education enhances farmers' climate change awareness and capacity to implement improved agricultural practices.

Extension officers corroborated many of these observations, identifying overlapping socio-economic, institutional, and policy-related factors that influence adoption. Education and awareness were repeatedly emphasized as critical enablers. As one key informant put it, *"Education opens the mind. A farmer who can read simple brochures or follow a radio program gains more than one who cannot."* According to Antwi-Agyei et al. (2021), Education is a cornerstone of climate resilience. KI5 admitted, *"Many communities are underserved. We do what we can, but with few staff, many farmers go months without direct support."*

Economic barriers were also underscored, particularly for women. They noted that many female farmers operate on borrowed land or small plots, excluding them from major financial schemes and limiting their ability to invest in modern strategies. At the institutional level, the Cocoa Health and Extension Division (CHED) and COCOBOD were recognized as key actors, yet policy inconsistencies and funding shortfalls often delayed or weakened programme implementation.

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While Ghana's National Climate-Smart Agriculture and Food Security Action Plan (2016–2020) supports farmer adaptation broadly, its grassroots execution has been uneven (Antwi-Agyei et al., 2021).

Local governance structures and farmer cooperatives emerged as important mediators, often providing more direct support than formal institutions. One respondent observed, *"In some communities, the farmer cooperatives are stronger than the formal institutions. They set norms and help farmers access support."* Such local-level structures play an important role in coordinating training, distributing inputs, and resolving land disputes.

3.5. The perceived effectiveness of traditional and modern adaptation strategies

Table 7: Perceived Effectiveness of Strategies (Farmers, n = 20)

Strategy Type	Frequency	Percentage (%)
Traditional (soil moisture, shade, intercropping)	13	65%
Modern (seedlings, irrigation, agrochemicals)	11	55%
Hybrid (combining both approaches)	9	45%

Source: Field Data, 2025

Traditional strategies were widely seen as effective for conserving soil and coping with short dry spells (65%). Modern strategies were credited with better disease and drought resistance (55%), though challenges with cost and technical knowledge reduced effectiveness for some. Nearly half the farmers (45%) recognised the strength of hybrid approaches, reflecting a growing view that integration of traditional and modern strategies provides the most resilience. The findings were consistent with Asare et al. (2021). Nonetheless, there was also recognition of their limitations, particularly in dealing with severe or increasingly unpredictable climate events. As one farmer observed, *"The rains do not come like before. The traditional ways cannot stop black pod disease."* This reflects a growing concern among farmers that traditional approaches alone may no longer be sufficient in the face of escalating climate pressures.

Modern strategies, in contrast, were viewed as more responsive to emerging threats such as disease outbreaks and prolonged droughts. Techniques like pesticide application, the use of disease-resistant cocoa varieties, and irrigation systems were credited with greater adaptability to recent climatic shifts. However, farmers noted that the effectiveness of these methods depended heavily on proper implementation, sustained support, and consistent use. For example, while pesticides were valued for managing black pod disease, some farmers struggled with determining the correct dosages or the appropriate timing of application, a challenge also documented by Partey et al. (2020). These constraints illustrate that access to knowledge and technical guidance is just as important as the tools themselves.

There was strong recognition of the benefits of integrating both traditional and modern approaches. Many farmers described hybrid strategies such as combining modern fertilizers with traditional mulching to improve soil health. This approach aligns with the "climate-smart agriculture" framework discussed by Bruinsma (2017), which advocates for the strategic blending of indigenous knowledge and scientific innovation to achieve resilience. Still, farmers repeatedly emphasized that the success of any method, traditional, modern, or hybrid, was strongly linked to the timeliness of interventions, access to relevant information, and economic viability. Delays in input delivery, inadequate financial resources, and lack of follow-up support were cited as key reasons why even proven strategies sometimes failed to deliver optimal results. Ultimately, while both sets of strategies were seen as valuable, their perceived effectiveness was multidimensional, shaped by the scale of climatic impacts, the farmer's socio-economic capacity, and the broader support ecosystem (Mertz et al., 2009).

Extension officers echoed the farmers' mixed but complementary assessments of traditional and modern strategies, offering nuanced insights into their strengths, weaknesses, and synergies. They noted that while traditional practices such as shade management, organic manure application, and crop diversification remain relevant, they are increasingly insufficient given the severity of current climatic shocks. *"The weather today is not what it used to be. Traditional practices alone can no longer withstand the intensity of droughts and erratic rainfall,"* one officer stated. Modern strategies such as the adoption of disease-resistant cocoa varieties, irrigation kits, and integrated pest management were viewed as better suited to recent challenges.

However, as one officer cautioned, these methods often falter when farmers lack the necessary tools, knowledge, or sustained support. The problem is compounded when expected results are not immediate, leading some farmers to abandon modern practices prematurely.

Extension officers stressed the value of complementarity between traditional and modern methods. One officer remarked, *"We find that traditional methods like composting work well with modern fertilizer application schedules. When blended properly, they enhance soil health and crop resilience."* Nevertheless, conflicts occasionally arose when the two systems offered contradictory recommendations, such as traditional tree-felling practices clashing with modern shade-tolerant cocoa promotion. Officers also noted weaknesses in the feedback loop between farmers and service providers. While cooperatives, community meetings, and field visits serve as primary feedback channels, one officer admitted that *"there's no formal mechanism to adjust programmes based on what we hear."*

4. Conclusion

This study examined cocoa farmers' preferences for traditional and modern climate adaptation strategies in Obuasi Municipality. Findings revealed that while traditional practices such as shade management, mulching, and indigenous weather forecasting remain central due to affordability and cultural familiarity, they are increasingly insufficient against more severe climatic shocks. Modern approaches, including improved seedlings, irrigation, and agrochemical use, were valued for their responsiveness to emerging threats but constrained by financial costs, technical knowledge gaps, and limited institutional support. A recurring theme was the recognition of hybrid approaches that integrate traditional and modern strategies as the most sustainable pathway to resilience. To achieve this, institutional actors such as the Cocoa Health and Extension Division, NGOs, and farmer cooperatives must strengthen climate adaptation support systems by improving access to finance, delivering timely inputs, enhancing extension coverage, and promoting context-specific training.

The study contributes to adaptation literature by highlighting how socio-economic characteristics, particularly Education, financial capacity, gender roles, and access to extension services, shape farmer preferences. It also underscores the role of cooperatives and grassroots institutions as critical mediators of adaptation support.

Several limitations must be acknowledged. The small, qualitative sample limits the generalisability of findings, and the study's geographic focus on Obuasi restricts wider applicability. In addition, the reliance on self-reported data may have introduced bias.

Consequently, it is recommended that policy interventions should prioritise gender-sensitive financial support, strengthen extension services, and promote participatory platforms that blend scientific knowledge with traditional practices. Furthermore, policymakers and researchers should establish a monitoring system combining farmer feedback, agro-ecological data, and impact metrics to refine and scale up effective strategies. Future research should employ mixed-method designs across multiple cocoa-growing regions to compare adaptation dynamics and assess the long-term effectiveness of hybrid approaches. Such measures will enhance the resilience of Ghana's cocoa sector while safeguarding farmer agency and cultural heritage.

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Trust and Usability of Climate-Resilience Messages Among Smallholder Farmers: A Protection Motivation Theory–Informed Qualitative Study in Adansi North, Ghana

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Abstract:

In Ghana, recurrent droughts threaten staple and vegetable crop production, making effective communication of Climate Resilience Messages (CRM) vital for strengthening farmers' adaptive capacity. This study explored farmers' perceptions of CRM sources, trustworthiness, and usability in drought-prone communities of Adansi North District, Ghana. A qualitative research design was employed, using three focus group discussions with 15 farmers and 20 key informants selected through purposive and snowball sampling. Data were analysed thematically to capture farmers' perceptions regarding CRM. Results showed that farmers were skeptical of modern forecasting systems. Traditional leaders and indigenous methods remain the most credible and trusted sources of climate information. The overly technical presentation of CRMs alienates many farmers. Agricultural extension officers are not viewed as sufficiently knowledgeable in delivering CRMs. The usability of CRM is constrained by four key issues: technical language, reliance on educated intermediaries, late delivery of forecasts, and poorly adapted formats. To be effective, CRMs must be delivered through trusted channels, simplified in language, aligned with agricultural decision-making cycles, and adapted to local contexts. The study underscores the importance of participatory, culturally sensitive communication strategies in building resilience among drought-affected communities.

Keywords: Climate Resilience Messages, Drought-Prone, Perception, Trustworthiness, Usability.

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1. Introduction

Climate change continues to present one of the most pressing development challenges of the 21st century, with Africa disproportionately affected due to its dependence on rain-fed agriculture and limited adaptive capacity. Across the continent, climate change manifests in the form of recurrent droughts, flooding, unpredictable rainfall patterns, soil erosion, and declining agricultural productivity (Coulibaly et al., 2020). These consequences undermine rural livelihoods, exacerbate poverty, and threaten food security, particularly among smallholder farmers who rely heavily on climate-sensitive resources for survival (Atiah et al., 2022).

Drought-affected communities are among the most vulnerable to climate change, as prolonged dry spells destroy crops, reduce water availability, and heighten household food insecurity (Graves & Kuleshov, 2020; Ebhuoma, 2022; Kondal et al., 2024). In Ghana, the agricultural sector remains the backbone of the economy, providing livelihoods for nearly half of the population and contributing significantly to the National Gross Domestic Product (GDP). However, recurrent droughts are posing serious threats to productivity, incomes, and food supply stability. In such communities, farmers are experiencing substantial yield losses, with reports indicating reductions of up to 25% below average for key crops such as maize, millet, rice, and vegetables (Sorgho et al., 2020). These losses have far-reaching implications for both household welfare and national economic resilience.

To mitigate these risks, effective communication of climate resilience messages (CRM) has emerged as a vital tool for enhancing farmers' adaptive capacity (Allart et al., 2024). Climate resilience messages are designed to inform communities about impending risks, promote proactive adaptation, and provide practical strategies for reducing vulnerability (Adu-Boahen, 2023). Such messages may include disaster preparedness plans, water conservation practices, crop diversification techniques, and ecosystem restoration approaches. When communicated with clarity, cultural sensitivity, and community participation, CRMs can empower smallholder farmers with the knowledge and confidence to make informed decisions during climate shocks (Tahernejad et al., 2024).

Despite their potential, the effectiveness of climate resilience messages in African rural contexts remains contested. Anecdotal evidence from drought-affected communities in Ghana suggests that farmers often perceive CRMs as unreliable, poorly contextualized, or inconsistent with their traditional knowledge systems (Kondal et al., 2024). Farmers hold adverse perceptions regarding the sources, trustworthiness, and usability of CRMs. These negative perceptions are particularly concerning given that farmers have historically relied on indigenous indicators of drought (Kom et al., 2023). This mistrust and misalignment between modern climate communication and farmers' lived realities can have serious consequences. Farmers may disregard them entirely, continuing to rely on outdated practices that reduce productivity and exacerbate vulnerability (Ebhuoma, 2022). Given the urgency of addressing drought impacts and safeguarding food security, it is critical to investigate how farmers perceive CRMs and whether these messages are viewed as trustworthy, usable, and contextually relevant.

A growing body of literature highlights the importance of communication strategies in building farmers' resilience to climate change (Zongho et al., 2023; Adaawen, 2021). Tung et al. (2024) emphasize that participatory communication approaches tailored to community social structures enhance climate adaptation efforts. Tahernejad et al. (2024) further demonstrate that farmers' resilience depends not only on environmental conditions but also on individual perceptions and psychological coping mechanisms. In Ghana, Adeboa and Anang (2024) found that socio-economic factors such as education, farm size, and radio access significantly influence the adoption of climate adaptation strategies. Similarly, Adu-Boahen (2023) observed that smallholder farmers employ a wide range of adaptive tactics, such as crop diversification and irrigation, when provided with accurate and timely climate information.

Yet, despite these insights, very few studies have focused explicitly on farmers' perceptions of climate resilience messages as a communication innovation. This gap is particularly evident in Ghana, where recurrent droughts threaten national food systems, but little is known about how farmers interpret, evaluate, and act upon CRMs. The main aim of this study, therefore, is to understand farmers' perceptions of Climate Resilience Messages (CRM) in drought-affected communities in Ghana. The specific objectives are to examine farmers' perception of CRM sources

and their trustworthiness and to ascertain farmers' perception of CRM usability.

Given the devastating socio-economic impacts of droughts in Ghana and the reliance of rural households on agriculture, this study is both timely and significant. Findings from this research will contribute to both policy and practice. Understanding farmers' perceptions is essential not only for improving communication design but also for ensuring that CRMs achieve their intended goal of fostering resilience in drought-prone communities. At the policy level, evidence will guide the design of targeted, farmer-centred communication strategies that are participatory, culturally relevant, and responsive to local realities. At the practice level, the study will inform extension agents, NGOs, and government agencies on how best to package and deliver CRMs in ways that resonate with farmers. More broadly, this research advances scholarly debates on climate communication in the Global South, filling an important knowledge gap in the literature on resilience, adaptation, and communication effectiveness.

2. Theoretical framework

Protection Motivation Theory (PMT) was introduced by Rogers (1975) and further revised in 1983 (Rogers, 1983) to explain the impact of persuasive communication on behaviour, with an emphasis on cognitive mechanisms underpinning the rationale to follow or not to follow a recommended behaviour. The theory was originally conceptualised for utilisation in the healthcare context (Conner & Norman, 2015). In terms of practical importance, PMT was one of the first theories focusing on the psychological conditions explaining the tendency of people to protect themselves. Due to the robustness of PMT, it has been used in different disciplines, such as psychology/health, sport science, tourism, environmental science, and marketing. In our present study, PMT provides a useful framework for understanding how farmers perceive and respond to climate resilience messages. The farmers' interpretation of climate change resilience messages is shaped by their perception of climate change and their vulnerability to its impacts on crop yields and livelihoods. If farmers view climate change as a severe and recurring challenge, they may pay closer attention to resilience messages. On the other hand, if they perceive climate change as a normal change or believe they are not highly vulnerable, their motivation to act may be lower. How farmers react after the messages are received is also very important. Farmers are more likely to adopt climate resilience practices if they perceive the recommended strategies are effective in reducing risks (response efficacy). Furthermore, their willingness to implement such practices depends on their confidence in their ability to carry them out (self-efficacy) and whether the costs, such as financial resources, labour, or time, are manageable. If messages do not address these concerns, farmers may reject or ignore them.

3. Research methodology

3.1. Study area

Adansi North District is one of the administrative districts in the Ashanti Region of Ghana, with its capital at Fomena, located along the Kumasi–Cape Coast main road. The district lies within a longitude of 1.5°W and a latitude of 6.3°N. It is bounded to the south by Adansi South District, to the north-east by Amansie East District, to the south-west by Obuasi Municipality, and to the west by Amansie Central District. The district covers a total land area of 1,140 square kilometres, representing 4.67% of the total land area of the Ashanti Region. It is composed of 94 communities, 35 electoral areas, seven area councils, and two constituencies (Fomena and Asokwa). The total population of the district is estimated at 76,000, comprising 36,936 males and 39,064 females (2000 census). The natural vegetation of the district falls within the semi-deciduous forest zone, and soils are dominated by forest ochrosols, which are generally fertile and suitable for diverse agricultural production. The climate is semi-equatorial, with an annual average temperature of between 26°C and 30°C. Rainfall is bimodal, with two distinct wet seasons, and the annual total ranges between 1,250 mm and 1,750 mm. Agriculture remains the dominant economic activity in the district, with most farmers engaged in mixed cropping, mono-cropping, and mixed farming. Major staple crops include maize, cassava, plantain, cocoyam, yam, and rice, while vegetables such as cabbage, pepper, tomato, okra, and garden eggs are also widely cultivated. Cocoa and oil palm serve as the leading cash crops. In terms of performance, maize, cassava, yams, cocoyams, and plantains remain the backbone of crop production. Between 2009 and 2010, maize cultivation declined from 10,800 hectares to 4,014

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hectares, with corresponding production dropping from 20,520 metric tonnes to 7,626.6 metric tonnes. Cassava production also fell sharply from 132,122 metric tonnes in 2009 to 81,254.8 metric tonnes in 2010. Conversely, yam production improved within the same period, increasing from 6,365 metric tonnes to 10,100.1 metric tonnes, reflecting both expansion in cultivated area and increased yields. Plantain and cocoyam, however, showed a decline in both area and output. These trends indicate fluctuating production levels shaped by climatic and agronomic challenges (Ghana Statistical Service, 2012).

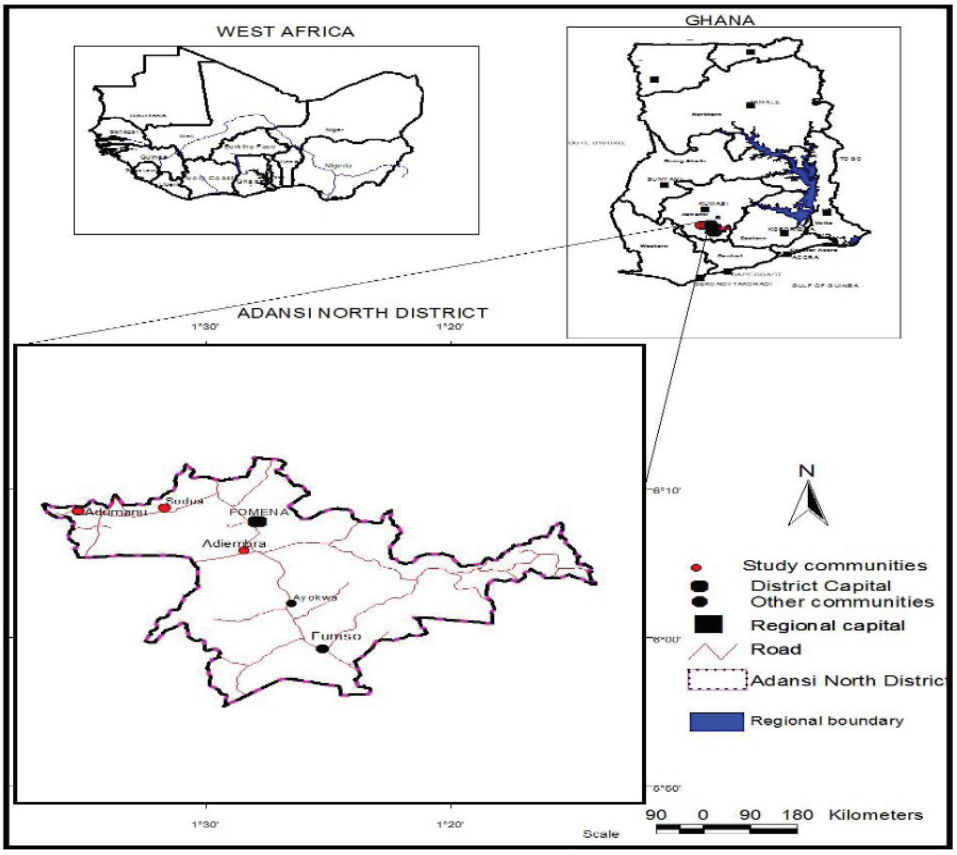

Figure 1: Map of Adansi North District

3.2. Study population and design

The study population comprised smallholder farmers residing in the Adansi North District of Ghana, a location that has in recent years experienced recurrent droughts and rainfall variability. The district was selected because agriculture remains the main source of livelihood for its population, and the effects of drought have been widely reported to undermine both productivity and household food security. Given the exploratory nature of the research questions, which sought to understand farmers' perceptions of Climate Resilience Messages (CRMs), a qualitative research design was adopted. Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs) were used to generate rich, detailed insights into farmers' experiences, perceptions, and attitudes towards CRMs. This design was considered most appropriate since it allows for the exploration of meanings and lived experiences that cannot easily be captured through quantitative surveys.

3.3. Sampling procedure

Due to the dispersed nature of farming households in Adansi North and the fact that not all farmers have directly experienced drought or exposure to CRMs, it was not feasible to access the entire population. Instead, the study employed purposive and snowball sampling techniques to identify participants. Purposive sampling ensured that only individuals with relevant experience, such as smallholder farmers who had lived in the district for at least five years and who had encountered drought impacts, were included. Additional selection criteria considered farmers' involvement in decision-

making within their households, as well as variation in gender, age, and crop types cultivated. This was intended to capture a breadth of perspectives while ensuring that participants possessed adequate knowledge of the subject matter. To complement purposive selection, snowball sampling was used to reach farmers who might otherwise be difficult to locate due to their dispersed settlements. Three independent community "seeds" were used to begin referral chains, thereby reducing the risk of homogeneity that can arise when snowballing relies on a single network. This integrated approach was adopted to improve both the precision of the sample and the richness of the data collected.

A total of three FGDs were organised with 15 farmers in all, alongside 20 key informant interviews conducted with extension officers, community leaders, and household heads. They were selected from three communities within the District: Apomposo, Bura, and Aboabo. Each FGD comprised five participants to ensure manageable group sizes that allowed for deeper discussion and more balanced participation. Although the numerical size of the sample appears small, the qualitative research was guided by the principle of information power rather than statistical representativeness. Farmers recruited for this study had rich experiential knowledge of drought impacts and interactions with CRMs, which ensured that each participant contributed high-value insights. Data saturation was closely monitored during the analysis. It was reached after the third focus group discussions and final set of key informant interviews (KIIs), when no new information appeared in the transcripts. This demonstrates that the sample size was adequate to achieve the study's objectives.

3.4. Data collection procedures

Data were collected within the month of June 2025. The research team first consulted with district agricultural officers and local leaders to introduce the study and gain access to participants. Informed consent was obtained from all participants prior to data collection, with assurances of confidentiality, anonymity, and voluntary participation.

FGDs lasted not more than 45 minutes, while KIIs lasted not more than 60 minutes. All sessions were conducted in the local language (Twi), recorded with permission, and supported with note-taking. The FGD guide was semi-structured and explored themes including farmers' experiences with drought, sources of climate information, perceptions of the credibility and usefulness of CRMs, and barriers to adoption. The KII guide was tailored for key informants, with emphasis on their role in communication processes and their perceptions of how farmers receive and use CRMs. Both instruments were piloted in a nearby community outside the study area, after which minor refinements were made to ensure clarity and cultural appropriateness.

3.5. Data analysis

Audio recordings were transcribed verbatim in the local language before being translated into English by the research team members. To ensure accuracy, a random selection of transcripts was back-translated into the original language and compared against the recordings. All transcripts were anonymised and assigned unique codes to protect participant identity. The transcripts, field notes, and reflective memos were organised manually for systematic analysis and secure storage.

Thematic analysis was employed to identify and interpret recurring patterns within the data. The analytic process followed Braun and Clarke's six-step framework. First, two researchers independently read and re-read the transcripts to become familiar with the data. Second, initial codes were generated both inductively from the data and deductively based on the research objectives (e.g., codes such as "trust in source," "usability," and "message clarity"). Third, codes were collated into broader categories to form candidate themes. Fourth, themes were reviewed and refined to ensure they accurately represented the data and were supported by sufficient evidence. Fifth, themes were defined and labelled with clear boundaries. Finally, analytic narratives were developed to connect the themes to the study objectives and the broader literature on climate communication.

Inter-coder reliability was tested by having two coders independently code 20% of the transcripts. Cohen's Kappa values indicated acceptable agreement (≥0.70). Any discrepancies were resolved through discussion and consensus, which led to the refinement of the codebook. Triangulation across FGDs, KIIs, and field notes enhanced the robustness of the findings. Data was analysed with the assistance of Allyze (a qualitative data analysis software).

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Table 1: Farmers' perceptions of Climate Resilience Messages (CRMs): Key Themes, Sub-Themes, Illustrative Quotes, and Literature Link

Theme	Farmer Perception / Finding	Linked PMT Construct	Interpretation	Representative Quote
The Crisis of Authority: Trust and Mistrust in Forecasting Systems	Forecasts were inconsistent, often failing to materialise, leading to frustration and mistrust.	Threat Appraisal (Severity & Vulnerability)	Inaccurate forecasts reduce farmers' perception of drought severity and vulnerability, weakening their motivation to act.	*"In fact, I consider the climate resilience message sources I receive not trustworthy. They sometimes predict a higher precipitation rate, but it would never come to pass, and report different figures in the evening."*
Traditional Wisdom vs. Modern Channels: Competing Sources of Authority	Farmers prefer traditional leaders' predictions over modern channels (radio, social media, TV).	Coping Appraisal (Response Efficacy)	Trust in indigenous knowledge increases perceived effectiveness of advice, while mistrust in institutional forecasts reduces adoption of CRM.	*"Personally, whilst I think that relying on these messages from social media handles is okay, I think these modern channels are not the best as compared to our traditional leaders. These leaders have never failed in their predictions."*
The Practicality Paradox: When Climate Information Becomes Too Technical	Messages are overly technical (e.g., "precipitation rate") and disconnected from farmers' realities.	Self-Efficacy	Farmers feel unable to act on technical advice, reducing confidence in their capacity to apply resilience measures.	*"If the message presents a precipitation rate of 40 inches, I would find it difficult to understand what that really means. I mostly ask my child, who is educated, to translate that for me."*
Fragile Expertise: The Knowledge Gap in Extension Services	Extension officers are seen as insufficiently knowledgeable on drought issues.	Response Efficacy & Self-Efficacy	Lack of credible intermediaries lowers confidence in both the advice and farmers' ability to implement it effectively.	*"I do not perceive agric extension officers to be that well-informed to give us reliable messages on drought resilience. It requires someone with greater expertise."*
Reliability in Question: Inconsistency Across CRM Sources	Farmers find CRMs inconsistent and inaccurate; they prefer indigenous signs as more reliable.	Response Costs	Acting on unreliable information risks wasting labour, inputs, and time, making farmers less likely to adopt adaptive practices.	*"The indigenous means of receiving climate resilience messages are inarguably accurate... our great fathers never knew modern sources, yet they harvested greater crops."*
The Comprehension Gap: When Technical Language Alienates Farmers	Farmers with limited education struggle to understand CRMs and depend on relatives for translation.	Self-Efficacy	Low confidence in understanding technical content reduces motivation to follow recommendations.	*"I sometimes struggle to understand what information the message is trying to send across... I would find it difficult to understand what that really means."*
Lost in Translation: Usability Barriers and the Risk of Exclusion	Reliance on educated family members to interpret CRMs creates dependency.	Response Costs	Extra effort and reliance on others increase perceived costs, discouraging engagement with CRMs.	*"The technique I mostly adopt is to ask my child, who is educated, to translate that for me, who might not always be available."*
The Tyranny of Timing: When Forecasts Arrive Too Late	CRMs often arrive during or after drought events, reducing their usefulness for planning.	Response Efficacy	Messages perceived as ineffective when untimely, leading farmers to ignore them in decision-making.	*"The message mostly comes after or exactly when the drought is already in place, making it difficult to decide."*
Form vs. Function: The Disconnect in Message Presentation	Messages delivered in clumsy formats (radio/verbally) without practical demonstrations.	Response Efficacy & Self-Efficacy	Poor formats limit farmers' ability to understand and apply advice, undermining both confidence and belief in CRM effectiveness.	*"I'm not happy with the manner in which the message is sent at all. The message is presented in a clumsy manner, and I mostly do not even know what was actually presented."*

Source: Authors' Construct, 2025

Table 1 presents the thematic analysis of farmers' perceptions of climate resilience messages (CRMs). The themes capture both the trust dimension, where issues of authority, inconsistency, and knowledge gaps undermine confidence in formal CRM sources, and the usability dimension, where technical language, poor timing, and inadequate formats restrict farmers' ability to act on the information provided. Each theme is linked to the key constructs of the Protection Motivation Theory (PMT), highlighting how perceptions of severity, vulnerability, response efficacy, self-efficacy, and response costs shape farmers' engagement with CRMs. Representative quotes from farmers are included to illustrate how these perceptions manifest in practice, ensuring that the analytical categories remain grounded in lived experiences.

4. Results and discussion

4.1. Farmers' perception of CRM sources and trustworthiness

Table 2: Farmers' perception of CRM sources and trustworthiness

Theme	Frequency	Percent (%)
The Crisis of Authority: Trust and Mistrust in Forecasting Systems	22	62.9
Traditional Wisdom vs. Modern Channels: Competing Sources of Authority	20	57.1
The Practicality Paradox: When Climate Information Becomes Too Technical	16	45.7
Fragile Expertise: The Knowledge Gap in Extension Services	18	51.4
Reliability in Question: Inconsistency Across CRM Sources	23	65.7

Source: Field Data, 2025

Table 2 presents the descriptive results on farmers' perceptions of climate resilience message (CRM) sources and their trustworthiness. The findings are based on responses from 35 participants across focus group discussions and key informant interviews. The results show that mistrust in forecasting systems (62.9%) and inconsistency across CRM sources (62.9%) were the most frequently expressed concerns. Farmers also highlighted the preference for traditional leaders (54.3%) over modern channels, reflecting the perceived authority and contextual relevance of indigenous knowledge. In addition, a significant proportion of participants (51.4%) raised concerns about the limited knowledge and credibility of agricultural extension officers. Meanwhile, 40% of farmers pointed out the technicality of CRM packaging, which made the messages difficult to interpret.

1. **The Crisis of Authority:** ***Trust and Mistrust in Forecasting Systems***

   The discussions on perception of CRM sources and trustworthiness revealed the lack of trust in the information received by farmers. This is because most of the farmers mentioned that they do not believe the source of the climate resilience messages they receive for their farming decisions. They noted that predicted rainfall patterns often failed to materialise or were contradicted by later updates. Such inconsistencies created frustration, particularly for those who relied on forecasts to plan daily farming activities. The erosion of trust appears strongly linked to past experiences with failed drought forecasts, which tend to diminish confidence in subsequent messages. This observation is consistent with findings by Adeboa and Anang (2024), who demonstrated that farmers' adoption of climate adaptation strategies is shaped by prior drought experiences and contextual location effects. One of the farmers had this to say: "*In fact, I consider the climate resilience message sources I receive not trustworthy. They sometimes predict a higher precipitation rate, but it would never come to pass, and they report different figures in the evening. This can be very worrying in most cases because I plan my farming activities after I check in the morning*". Farmers' doubts about CRM sources, shaped by failed or contradictory forecasts, reflect a breakdown in threat appraisal under Protection Motivation Theory (PMT). When forecasts are inaccurate, the *perceived severity* of drought risks is blurred, and farmers' *perceived vulnerability* weakens, reducing their motivation to adopt protective measures (Rogers, 1975; Rogers, 1983).

2. **Traditional Wisdom vs. Modern Channels:** ***Competing Sources of Authority***

   After ascertaining the perceptions of farmers on the trust in the source, we sought to inquire about whether farmers prefer to receive the

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message from local leaders rather than from modern channels like television, radio, social media apps, etc. It became evident from the discussion that local farmers prefer to receive CRM from traditional leaders. Another farmer confirmed this by stating that: *"Personally, whilst I think that relying on these messages from social media handles is okay, I think these modern channels are not the best as compared to our traditional leaders. These leaders have got the necessary experience in studying the terrain and predicting whether there may be a drought or not, and truth be told, they have never failed in their predictions*". This suggests that farmers prefer to receive the CRM from traditional sources rather than modern ones. This could be attributed to a disconnect between CRM sources and local realities. Climate resilience messages are usually produced at the regional level, which are less tailored to local farming systems. The finding is similar to Zongho et al. (2023), who concluded that the indigenous peoples' perceptions of climate change were based on signs like an increase in temperature, heatwaves, prolonged drought spells, and reductions in rainfall. The preference for traditional leaders over modern media channels illustrates the central role of source credibility in influencing response efficacy within PMT. Farmers perceive traditional knowledge systems as more effective in managing risk than institutional forecasts. According to PMT, if people doubt the efficacy of the recommended action or its source, their protective motivation declines (Conner & Norman, 2015).

3. **The Practicality Paradox: *When Climate Information Becomes Too Technical***

Another important theme relates to how CRM is packaged and communicated. Farmers described the format of messages as overly technical, clumsy, or difficult to interpret, particularly for those with limited formal education. Technical terms like "precipitation rate" were seen as confusing and disconnected from practical farming contexts. Some farmers indicated that they relied on younger, educated relatives to interpret the content for them, which created dependency and further highlighted accessibility barriers. Others argued that the format appeared to have been designed without sufficient consideration of farmers' needs. The lack of farmer-centred packaging undermined not only comprehension but also the perception that CRM was tailored to their realities (Calvel et al., 2020). Farmers, therefore, suggested that messages should be simplified, contextualised, and communicated through more practical, farmer-friendly formats, such as local language radio broadcasts or demonstrations. Overly technical CRMs reduce self-efficacy under PMT, as farmers lack confidence in their ability to interpret or act on complex information. Unless individuals feel capable of performing the recommended behaviour, they are unlikely to adopt it, even if they accept the risk.

4. **Fragile Expertise: *The Knowledge Gap in Extension Services***

The study sought to explore whether present extension officers who proffer climate resilience messages are deemed knowledgeable and reliable. It seems that farmers consider the extension officers to be knowledgeable enough. This is the response from one of the farmers: *"I do not perceive agricultural extension officers to be that well-informed to give us reliable messages on drought resilience. This is because predicting drought situations can be tricky, especially during rainy seasons. It therefore requires experience and someone with greater expertise to offer a reliable climate message rather than agricultural extension officers*". This means that farmers perceive agricultural extension officers to be less knowledgeable and unreliable in terms of climate resilience messages. This result could be a result of limited training on climate resilience issues, whereby farmers notice a struggle in the interpretation of drought forecasts. Similarly, Sorgho et al. (2020) and Calvel et al. (2020) reported that informational/knowledge barriers to climate change adaptation create a sense of fear and helplessness in farmers' ability to sustain their lifestyle and food insecurity. Farmers' perception that extension officers lack sufficient knowledge undermines both response efficacy and self-efficacy, as described in PMT. If the messenger lacks credibility, farmers doubt the effectiveness of the advice (response efficacy) and their

own capacity to implement it (self-efficacy), leading to disengagement from resilience practices.

5. **Reliability in Question:** ***Inconsistency Across CRM Sources***

We also sought to establish whether farmers in the Adansi North district receive reliable and quality climate resilience messages from the source they depend on. Most of the farmers agreed that CRM sources are utterly inconsistent and inaccurate. They explained that: "*The indigenous means of receiving climate resilience messages are inarguably accurate and consistent when relied upon to guide our farming practices. This has been the way to predict drought over the years and has worked for our great fathers. They never knew any modern source of receiving climate resilient messages, but I can say for a fact that they thrived in farming and harvested greater crops*". It means that the prevailing CRM sources relied upon by the farmers are not consistent and accurate. The unreliability and inaccuracy of the CRM sources could be attributed to data gaps and infrastructure challenges. This is because in Ghana, several districts are known to have sparse weather station coverage and weak data stream systems. Hence, forecasts that rely on outdated or incomplete data sets could be misleading, resulting in inaccuracy (Andries et al., 2023). The inconsistency of forecasts increases response costs in PMT terms. Farmers perceive that acting on unreliable information risks wasted labour, time, or inputs. Since PMT posits that high response costs diminish protective behaviour, inconsistent forecasts discourage farmers from adopting adaptive measures.

4.2. Farmers' perception of Climate Resilience Messages usability

Table 3: Farmers' perception of Climate Resilience Messages usability

Theme	Frequency	Percent (%)
The Comprehension Gap: When Technical Language Alienates Farmers	21	60.0
Lost in Translation: Usability Barriers and the Risk of Exclusion	17	48.6
The Tyranny of Timing: When Forecasts Arrive Too Late	24	68.6
Form vs. Function: The Disconnect in Message Presentation	19	54.3

Source: Field Data, 2025

Table 3 presents the descriptive findings on farmers' perceptions of CRM usability. The data demonstrate that timeliness was the most critical usability challenge, with 68.6% of participants reporting that forecasts often arrived too late to inform farming decisions. This highlights a major structural weakness in the alignment of CRM with agricultural decision-making cycles. Equally important were concerns about technical language, raised by 54.3% of farmers, which limited comprehension and reduced self-efficacy in applying the information. A further 48.6% of participants pointed to the high response costs associated with depending on others to interpret CRM, while 42.9% criticised the presentation formats as impractical or ill-suited to their needs. These results confirm that even when CRMs are available, their usability is undermined by barriers of timing, complexity, and inappropriate delivery formats, reducing their effectiveness in guiding adaptive action.

1. **The Comprehension Gap:** ***When Technical Language Alienates Farmers***

One key characteristic of a CRM for farmers is that it has to be easy to understand. The implication is that these farmers are mostly found in rural settings and are not adequately familiar with the way in which the message is presented (Gonzalez, 2024). The analysis revealed that climate resilience messages on drought occurrence are usually difficult to understand. One farmer insisted that: "*I sometimes struggle to understand what information the message is trying to send across. For instance, if the message presents a precipitation rate of 40 inches, I would find it difficult to understand what that really means. The technique I mostly adopt is to ask my child, who is educated, to translate that for me, who might not always be available*". The conclusion is that farmers find it difficult to understand climate resilience messages. The reason is that CRM often uses technical language to convey climate messages (Gonzalez, 2024; Graves & Kuleshov, 2020). Hence, farmers with limited formal education may find such terms

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as confusing and relatively abstract (Evans et al., 2011). The result mirrors the work of Tung et al. (2024), who assessed the difficulties in communicating about climate change in rural areas and found that different kinds of practical knowledge about the environment were being passed around in different ways in the communities that were studied, and showed how these were important for the development of genuinely participatory and two-way communication strategies. Duarte et al. (2024) advocate for simplified tools with intuitive interfaces that can help farmers manage agricultural activities and understand climate information better. Complex climate terminology weakens self-efficacy in PMT. Farmers doubt their ability to apply abstract technical forecasts, reducing their willingness to act on them. PMT stresses that self-efficacy is central: without confidence in their ability to act, individuals disengage even when they accept the threat (Rogers, 1975; Conner & Norman, 2015).

2. **Lost in Translation:** ***Usability Barriers and the Risk of Exclusion***

A recurring theme that emerged from the discussions was the difficulty farmers faced in comprehending climate resilience messages (CRM) on drought. Many participants explained that the terminology and structure of the information were often too technical, leaving them unsure how to translate the forecasts into actionable strategies. For instance, when rainfall was described in precise measurements, such as "40 inches of precipitation," farmers with limited formal education struggled to relate this figure to their daily farming practices. In such cases, they depended on more educated family members for interpretation; an arrangement that was neither reliable nor sustainable. This suggests that while the messages were available, their usability was severely constrained by linguistic and technical barriers. As Tung et al. (2024) observed, effective communication in rural communities requires sensitivity to local knowledge systems and social structures; otherwise, even well-intentioned messages risk alienating their intended audiences. The need to depend on educated relatives to interpret CRMs raises response costs in PMT. Extra effort and dependency discourage adoption, as PMT predicts that protective behaviours are less likely when they demand high cost, time, or resources (Rogers, 1983).

3. **The Tyranny of Timing:** ***When Forecasts Arrive Too Late***

Beyond the language used, the timeliness of CRM was another major concern. Farmers consistently argued that the forecasts and drought warnings often arrived after climatic events were already unfolding. This mismatch between message delivery and the agricultural calendar reduced the practical value of the information. For example, adaptation strategies such as shifting planting dates, selecting drought-tolerant varieties, or planning irrigation require advance notice. Yet, farmers emphasised that messages tended to come "after or exactly when the drought is already in place," leaving them with few viable options. The frustration expressed here underscores a structural weakness in climate communication: forecasts, however accurate, lose relevance if they are not aligned with farmers' decision-making cycles. This observation supports Goraldo et al. (2023), who argue that the timing of information is as critical as its accuracy in determining its usefulness for climate adaptation. Delays can lead to missed opportunities for adaptation (Ebhuoma, 2022). Many farmers perceive seasonal forecasts as unreliable, which can lead to underutilization, especially when forecasts are not provided in advance of decision-making periods (Kondal et al., 2024). Tailoring the timing and content of drought warnings to align with agricultural practices enhances the relevance and uptake of information (Calvel et al., 2020). Delayed forecasts erode response efficacy in PMT. If information comes after drought has already set in, farmers view it as ineffective in reducing risk. PMT highlights that people act only when they believe recommended behaviours can meaningfully mitigate the threat before it materializes (Conner & Norman, 2015; Rogers, 1975).

4. **Form vs. Function:** ***The Disconnect in Message Presentation***

Equally significant were concerns about the format in which messages were delivered. Farmers described the presentation of CRM

as "clumsy" and ill-suited to their needs, with many admitting they could not grasp the intended meaning. The dissatisfaction here was not merely about clarity but about a deeper disconnect between message designers and end-users. Farmers felt that if their realities were adequately considered, the messages would be tailored in ways that were both practical and accessible—for instance, through demonstrations, visuals, or context-specific examples. Current formats, often dependent on radio or verbal announcements, were seen as inadequate for conveying complex adaptation strategies. This perception resonates with the findings of Kihara and Nabushawo (2024), who emphasise that climate communication often fails because designers make assumptions about farmers' knowledge and capacities rather than engaging directly with them. Poorly adapted formats undermine both response efficacy and self-efficacy in PMT. Farmers perceive that the advice is neither usable nor suited to their needs, reducing confidence in both the effectiveness of the recommendations and their ability to apply them (Rogers, 1983; Conner & Norman, 2015; Rogers, 1975).

5. Conclusion

The study explored farmers' perceptions of climate resilience messages (CRMs) in Adansi North District, with a particular focus on the trustworthiness of message sources and the usability of the information provided. The findings reveal several critical insights: Farmers expressed deep skepticism towards modern forecasting systems, primarily due to inconsistencies and failed predictions. This mistrust has weakened farmers' confidence in using CRMs for decision-making and reduced their motivation to adopt recommended resilience measures. Traditional leaders and indigenous methods remain the most credible and trusted sources of climate information. Farmers perceive these systems as more reliable and context-specific compared to modern institutional forecasts, which are often seen as detached from local realities. The overly technical presentation of CRMs alienates many farmers, especially those with limited formal education. Difficult terminology and abstract measurements reduce comprehension and create dependence on others for interpretation, undermining self-efficacy and discouraging independent action. Agricultural extension officers are not viewed as sufficiently knowledgeable in delivering CRMs. This knowledge gap reduces farmers' trust in extension services and weakens the credibility of institutional communication channels. Farmers frequently encounter conflicting information across different sources, which increases response costs and discourages reliance on CRMs. Poor data infrastructure, including limited weather station coverage, contributes to this inconsistency. Even when CRMs are available, their usability is constrained by four key issues: technical language, reliance on educated intermediaries, late delivery of forecasts, and poorly adapted formats. These weaknesses collectively reduce the effectiveness of CRMs in supporting timely and informed agricultural decisions. Delayed forecasts were identified as the most significant barrier. Farmers repeatedly emphasised that CRMs often arrive too late to guide meaningful adaptation strategies, diminishing their practical value.

Government and meteorological agencies should strengthen the infrastructure for climate data collection by expanding the network of weather stations in rural districts. CRMs should be packaged in farmer-friendly formats, using simple language, local dialects, and visual aids (e.g., charts, pictograms, or community demonstrations). Forecasts and drought warnings should be disseminated well in advance of planting and critical farming decisions. Development agencies and government bodies should integrate indigenous knowledge with scientific forecasts to enhance credibility and local relevance. Training programmes should be developed to improve extension officers' expertise in climate resilience and forecast interpretation. Farmers should be actively involved in the design, testing, and evaluation of climate communication tools. CRMs should be shared through a mix of communication platforms: radio, mobile phones, community meetings, and extension visits to increase accessibility. Climate services should be tailored to minimise costs associated with understanding and applying the information.

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Farmers' Experiences with Extension Services in Promoting Sustainable Land Use Practices in Fanteakwa South Municipality

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Abstract:

This study explored farmers' experiences with agricultural extension services in promoting sustainable land use practices in the Fanteakwa South Municipality of Ghana. Guided by participatory extension, social learning, innovation diffusion, and systems theory, the research adopted a qualitative exploratory case study design. Data were collected through focus group discussions with 20 farmers and eight key informants. Thematic analysis revealed that farmers accessed extension messages through group meetings, community information centers, radio programmes, and home visits. While farmers expressed general satisfaction with these methods, they highlighted differing preferences based on accessibility and interaction, with farm visits and group methods valued for their practical and interactive nature. Extension agents promoted practices such as soil fertility management, agroforestry, crop rotation, erosion control, and water conservation. Adoption, however, was constrained by financial limitations, lack of access to credit, and the technical complexity of extension messages. The findings underscore the need for farmer-centered extension approaches that integrate financial support mechanisms, participatory learning, and coordinated stakeholder engagement to enhance adoption and ensure the sustainability of land use practices in farming communities.

Keywords: Agricultural extension services, Farmer perceptions, Knowledge transfer, Sustainable land use practices.

1. Introduction

Agricultural extension services have emerged as critical intermediaries between scientific knowledge and farmer practice in the global push for sustainable agriculture (Priya et al., 2025). With intensifying threats from climate change, soil degradation, and biodiversity loss, extension systems are increasingly tasked with not only enhancing productivity but also fostering resilience and ecological sustainability (Yang et al., 2024; Harvey et al., 2014). Their role is no longer confined to transferring technologies; rather, they are positioned as facilitators of behavioural change, mediators of local and scientific knowledge, and agents of inclusive rural development (Priya et al., 2025).

Extension services are therefore expected to serve as vehicles for disseminating strategies such as conservation agriculture, agroforestry, integrated soil fertility management, and integrated pest management. However, the degree to which these practices are adopted remains inconsistent, underscoring the persistent disconnect between extension objectives and farmer realities (Kwanya et al., 2021). The effectiveness of extension services in bridging the gap between sustainable agricultural innovations and farmer adoption has become a focal point of research and policy (Hameed & Sawicka, 2023).

The complexity of adoption challenges necessitates examining the lived experiences of farmers in their interactions with extension services. Adoption of sustainable practices is shaped not only by access to technical advice but also by socio-economic conditions, institutional capacity, and cultural contexts (Tham-Agyekum et al., 2024; Olabanji & Chitakira, 2025). While extension officers provide the conduit for scientific knowledge, farmers' willingness and ability to adopt recommended practices are mediated by farm size, education, access to resources, and historical experiences with agricultural interventions. This interplay demands that extension services be designed in ways that are participatory, inclusive, and context-specific, rather than reliant on one-way communication models (Lipper et al., 2014).

The role of extension in promoting sustainability has received increasing scholarly attention. Whereas extension services were historically oriented towards increasing yields and output, their focus has broadened to include ecological sustainability, resilience-building, and livelihood diversification (Schaafsma et al., 2018; Mungai et al., 2024). Programmes have promoted agroecological methods and soil health strategies with varying degrees of success. Yet adoption remains uneven across different farmer categories. For example, larger or better-resourced farmers are often better positioned to adopt recommended practices than their smallholder counterparts, who face acute resource constraints. This disparity underscores the limitations of conventional extension approaches and highlights the importance of context-sensitive programming (Lipper et al., 2014).

The literature points to a persistent gap between programme objectives and farmer adoption of sustainable land use practices (Wang et al., 2021). This gap is attributable to a complex set of barriers spanning economic, institutional, and socio-cultural domains. Economically, many sustainable practices demand significant upfront investments or entail temporary reductions in yields before long-term benefits accrue. In resource-constrained contexts, farmers often perceive these practices as risky and impractical without access to credit or risk management strategies. Institutional barriers further complicate adoption. Extension officers are often inadequately trained in participatory approaches and ecological principles, limiting their ability to effectively engage farmers. Moreover, structural challenges such as insufficient logistics, poor monitoring, and performance evaluation frameworks that emphasise quantity over quality contribute to weak service delivery. This creates a situation where extension programs may achieve high coverage rates but minimal behavioural change among farmers. Socio-cultural barriers are equally significant. Traditional extension approaches rooted in one-way communication models often disregard the wealth of indigenous knowledge farmers hold regarding soils, weather, crops, and pests (Radcliffe, 2020). By failing to integrate this knowledge into the design and dissemination of recommendations, extension programs risk alienating farmers and reducing their legitimacy. Furthermore, trust remains a decisive factor in shaping adoption. Farmers are more likely to adopt recommendations when extension agents demonstrate cultural sensitivity, local understanding, and a collaborative spirit (Oyetunde-Usman et al., 2020).

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Existing studies emphasise the critical role of extension services in promoting sustainable land use practices, particularly their capacity to disseminate innovations and improve farmers' technical efficiency (Hameed & Sawicka, 2023; Issahaku & Abdulai, 2020; Asare-Nuamah et al., 2019). While digital platforms are increasingly promoted, insufficient attention has been paid to inclusivity, particularly how gender, age, literacy, and infrastructure access mediate farmers' ability to benefit from these services (Mungai et al., 2024; Zulu et al., 2021). However, persistent challenges such as limited farmer engagement, inadequate training of extension workers, and weak dissemination strategies continue to undermine their effectiveness (Hameed & Sawicka, 2023). While recommendations such as capacity building for extension practitioners (Khwidzhili & Worth, 2020) and the adoption of pluralistic approaches to extension delivery (Danso-Abbeam, 2022) have been proposed, there is limited empirical evidence on how these strategies are operationalised in local contexts. Moreover, the literature provides insufficient insight into farmers' lived experiences of interacting with extension systems, particularly how cultural beliefs, financial constraints, and scepticism shape adoption decisions. This gap highlights the need for context-specific studies that capture both the opportunities and barriers faced by farmers in engaging with extension services for sustainable land use.

The urgency of strengthening extension services is heightened by accelerating climate change impacts and mounting global food security concerns. In Ghana, where agriculture remains central to rural livelihoods and national development, extension systems play a pivotal role in guiding farmers towards practices that simultaneously ensure productivity, resilience, and sustainability. However, the effectiveness of these systems in promoting sustainable land use practices remains poorly understood, particularly within local contexts such as the Fanteakwa South Municipality. Capturing farmers' perceptions, experiences, and satisfaction with extension services in this setting provides valuable insights into the barriers and facilitators of adoption, thereby informing the design of more effective extension models.

The study aims to address these gaps by pursuing the following objectives: to assess farmers' perceptions and satisfaction levels with current extension service delivery methods in promoting sustainable land use practices, identify the types of sustainable land use practices promoted by extension agents in the municipality and to identify the key barriers and facilitators that influence farmers' adoption of sustainable land use practices recommended through extension services in the Fanteakwa South Municipality.

2. Theoretical review and conceptual framework

The four theories that guide this study provide a comprehensive lens for understanding farmers' adoption of sustainable land use practices in the Fanteakwa South Municipality. Agricultural extension has shifted from the traditional Transfer of Technology (ToT) model, which treated farmers as passive recipients of innovations, toward participatory extension, which emphasises farmer agency, co-creation of knowledge, and adaptation to local realities. Grounded in constructivist learning, participatory extension highlights dialogue, experimentation, and mutual problem-solving as essential pathways to sustainability outcomes (Mungai et al., 2024).

In addition, Social Learning Theory explains adoption as a process shaped by peer interactions and collective experiences. Farmers are more likely to adopt practices that they observe being successfully implemented by trusted peers or within their networks. Extension services informed by this theory leverage farmer groups, peer-to-peer exchanges, and facilitation by extension officers to accelerate the spread of innovations (Yang et al., 2024; Ensor & de Bruin, 2022).

Innovation Diffusion Theory (Rogers) further accounts for how new practices spread across farming communities. Adoption is influenced by factors such as relative advantage, compatibility with existing practices, complexity, trialability, and observability of outcomes. In this context, extension agents serve as change agents who establish demonstration plots, encourage small-scale trials, and build trust to reduce uncertainty and promote uptake of sustainable practices (Oyetunde-Usman et al., 2020).

Finally, Systems Theory situates adoption within broader socio-ecological and institutional contexts. It emphasises the interconnectedness

of environmental, social, and institutional factors that shape farmer decision-making. From this perspective, effective extension aligns farm-level decisions with landscape-level sustainability goals and incorporates adaptive management through participatory monitoring and evaluation (Hameed & Sawicka, 2023).

The conceptual framework developed for this study illustrates how these four theoretical perspectives, participatory extension, social learning, innovation diffusion, and systems theory, interact to explain adoption outcomes. Extension delivery methods such as radio, community information centres, group meetings, and home visits are shown as key mechanisms through which farmers gain awareness, knowledge, and motivation. The framework also recognises that adoption is mediated by barriers such as financial constraints, inadequate access to credit, and complexity of extension messages, as well as facilitators including inclusive communication, participatory engagement, and institutional support. Ultimately, the framework demonstrates that the promotion of sustainable land use practices requires a multi-theoretical and multi-dimensional approach that integrates communication methods with systemic enablers and addresses contextual challenges in order to achieve meaningful and lasting adoption among smallholder farmers.

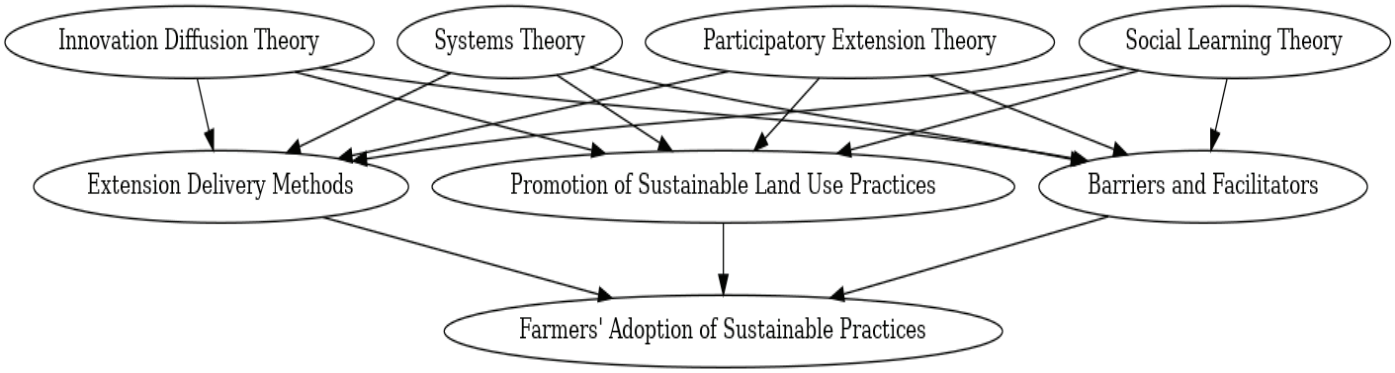

Figure 1: Conceptual framework

3. Methodology

3.1. Study area

The Fanteakwa South District Assembly is one of the 261 Metropolitan, Municipal and District Assemblies in Ghana and forms part of the 33 Municipalities and Districts in the Eastern Region. The Fanteakwa South District Assembly is carved out of the Fanteakwa North District as one of the 38 newly created and upgraded District Assemblies in 2018. Created with LI 2345, the Fanteakwa South District Assembly has its capital at Osino. It was inaugurated on March 15, 2018, alongside 37 other newly created districts. The District lies in the central part of the Eastern Region with a total land area of 803 square kilometers. It shares boundaries with Fanteakwa North District to the north, Kwahu South District to the north-west, East Akim Municipal and Atiwa East District to the south, and Yilo Krobo Municipal and Lower Manya Krobo Municipal to the east. It is bounded to the north by the Volta Lake. The current population of farmers in the Fanteakwa South District is over 86,154, with males being 42,625 and females being 43,529.

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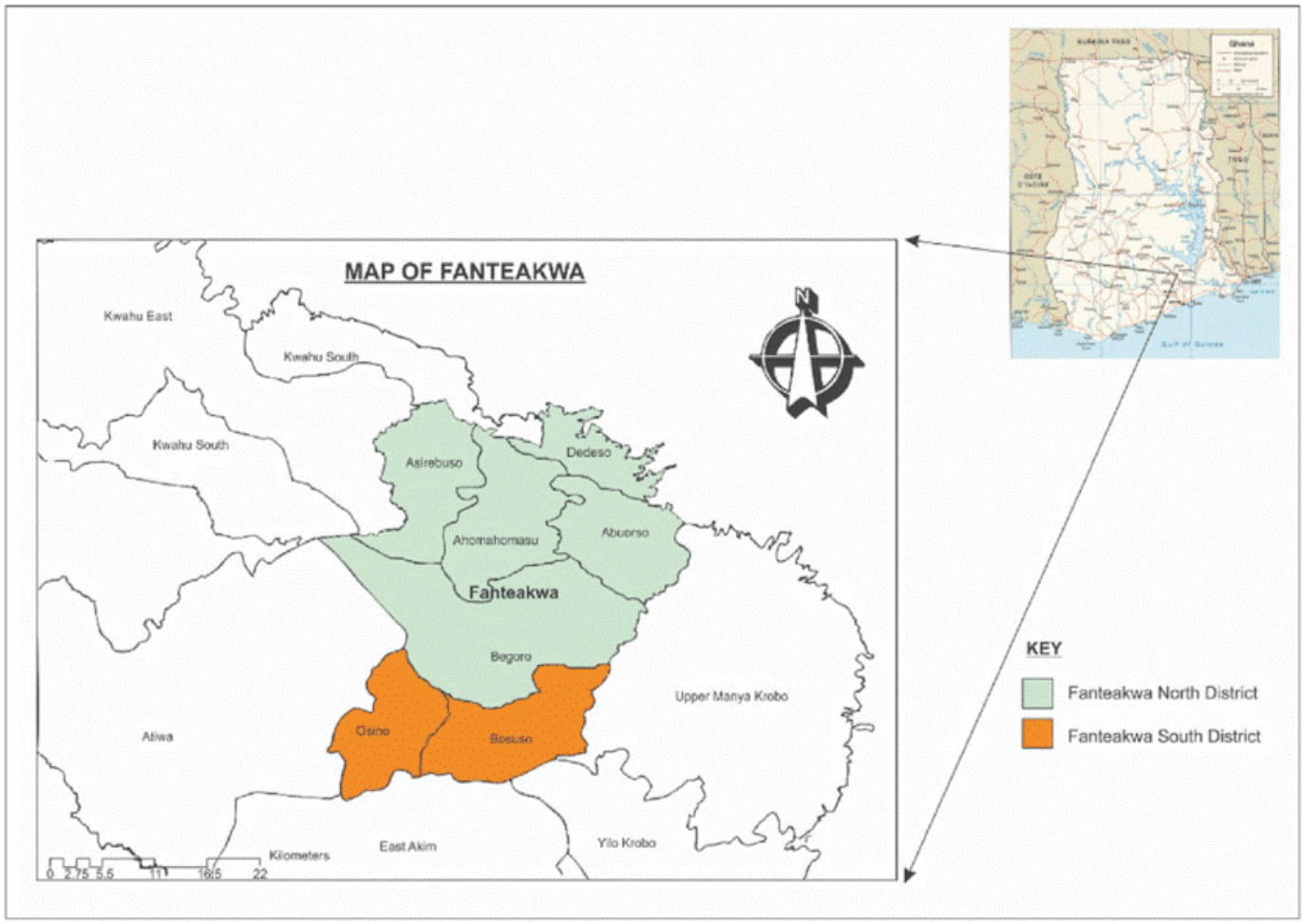

Figure 2: Map of Fanteakwa District

3.2. Study design

This study adopted a qualitative exploratory case study design, which was considered appropriate for understanding farmers' experiences with extension services in promoting sustainable land use practices in the Fanteakwa South Municipality. The exploratory design enabled an in-depth appreciation of how farmers perceived, interpreted, and responded to extension messages, while the case study approach made it possible to situate these experiences within their real-life social, cultural, and economic contexts. Anchored within the interpretivist paradigm, the study recognized that farmers' views and decisions were socially constructed, context-dependent, and best understood through their lived experiences.

3.3. Population

The target population for the study comprised all active farmers in the Fanteakwa South Municipality who had direct experience with agricultural extension services. These included smallholder, medium-scale, and commercial farmers cultivating staple and cash crops. Other relevant stakeholders, such as extension officers, traditional leaders, farmer-based organizations, input dealers, and NGO representatives, also formed part of the population, since their perspectives provided a more comprehensive understanding of how extension services operated within the community.

3.4. Sample size and sampling procedure

A purposive sampling strategy was employed to select respondents with rich and relevant experiences of extension services. A total of twenty farmers, representing different age groups, gender categories, and farm sizes, participated in focus group discussions. In addition, eight key informants were interviewed, comprising three agricultural extension officers, one traditional leader, one representative of a farmer-based organization, one input dealer, one NGO representative, and one successful lead farmer who was regarded as an

opinion leader in the community. This combination ensured diversity of views while capturing both farmer and institutional perspectives. Farmers were identified through community entry processes and referrals from existing participants. Recruitment continued until data saturation was achieved, when no new insights were emerging from the interviews and discussions.

3.5. Data collection procedure

Data collection was carried out through focus group discussions (FGDs) and key informant interviews (KIIs). The FGDs encouraged farmers to share collective experiences, compare perceptions, and reflect on the strengths and weaknesses of different extension delivery methods. Each FGD lasted between forty-five minutes and one hour and was conducted in Twi and Krobo (ethnic groups) to allow free expression. The KIIs lasted between thirty and forty minutes and provided deeper insights into extension delivery strategies, institutional challenges, and possible improvements. All sessions were audio-recorded with consent and supported by field notes.

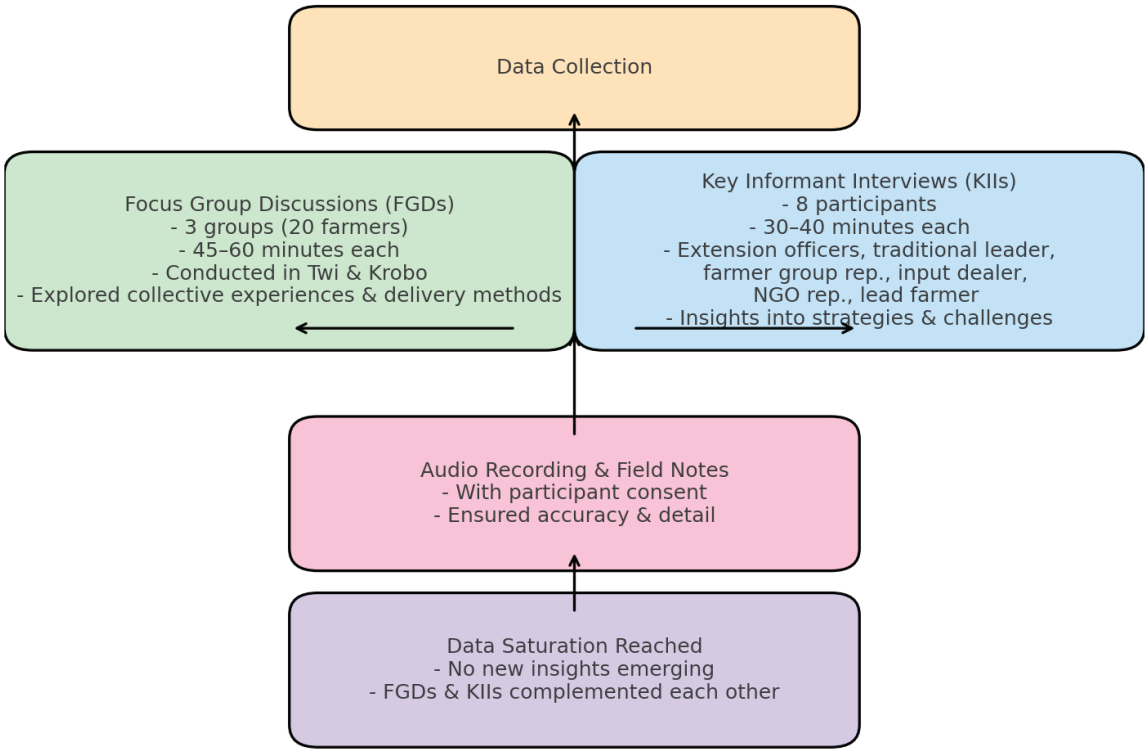

Figure 3: Data collection procedure

3.6. Data collection instruments

Semi-structured interview guides were developed to direct both the focus group discussions and key informant interviews. The farmer guide focused on their experiences with extension delivery methods, their perceptions of effectiveness, the barriers and facilitators they encountered, and their recommendations for improvement. The key informant guide, on the other hand, explored how extension was organized, the constraints faced by officers and institutions, and the ways in which extension services could better serve farming communities. The instruments were pre-tested in a neighboring community to ensure clarity and contextual relevance.

3.7. Data analysis

Data analysis was conducted using thematic analysis, drawing on Braun and Clarke's six-phase framework. First, the transcripts were read repeatedly to ensure familiarity with the data. Initial codes were then generated and grouped into emerging themes. These themes were reviewed, refined, and clearly defined to capture the central issues raised by participants. The themes were organized around the research objectives: farmers' perceptions of extension delivery, the barriers and facilitators to sustainable practice adoption, and their recommendations for improving extension services.

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3.8. Ethical approval

This study was conducted in accordance with established ethical standards for research involving human participants. Prior to data collection, the objectives and procedures of the study were clearly explained to all participants. Informed consent was obtained verbally and/or in writing, and participants were assured of the confidentiality and anonymity of their responses. Participation was entirely voluntary, and respondents were informed of their right to withdraw from the study at any stage without any consequences. All data were stored securely and used solely for academic purposes.

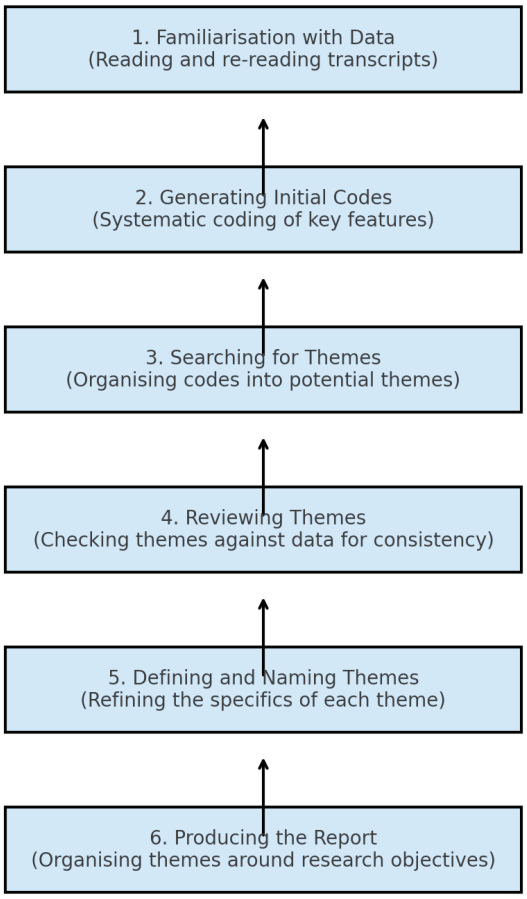

Figure 4: Phases of Thematic Analysis Used in this study (Braun & Clarke, 2006)

Table 1: Interview themes, questions, and theoretical linkages

Theme	Sample Interview Questions	Interesting Farmer Quotes (Field Data)	Link with Theories	No. of Questions
Farmers' perceptions and satisfaction with extension delivery methods	- How do you perceive the current extension service delivery methods? - Which method(s) of extension delivery do you find most effective in promoting sustainable land use practices? - Are there methods you find less helpful or unsatisfactory?	- *"My extension officer uses various methods... to me, the group method is the best way..." (R1)* - *"The community information center... very good... local language is used..." (R5)* - *"The radio is the one I prefer... it can reach a lot of people..." (R10)* - *"Home visits... we get the opportunity to ask questions..." (R11)* - *"The radio is not the best at all... I want to ask questions, but it is always difficult" (R2)*	**Participatory Extension Theory** – highlights the diversity of preferences and participatory communication. **Social Learning Theory** – group learning and interaction influence satisfaction.	4–5

Types of sustainable land use practices promoted.	- What sustainable land use practices have you learned from extension agents? - Which of these practices have you adopted, and why? - What challenges do you face in adopting these practices?	- *"The officers encouraged us to use compost instead of relying too much on chemical fertiliser" (R1)* - *"We were told to plant trees among our cocoa so the land does not lose its strength" - "The extension people told us not to plant maize on the same land every year" (R3)* - *"They showed us how to make ridges across the slope..." (R6)* - *"They talked about water harvesting, but it is not easy... we use barrels" (R10)*	**Innovation Diffusion Theory** – relative advantage, compatibility, and trialability of practices. **Systems Theory** – links farm-level adoption to broader environmental sustainability.	3–4
Barriers and facilitators to adoption	- What challenges prevent you from adopting sustainable land use practices? - What could make it easier for you to adopt these practices? - What role should government or extension services play in supporting adoption?	- *"I don't have the money to buy farming inputs... lack the financial power" (R14)* - *"The incentives given... are not enough" (R13)* - *"Our harvest... is nothing to write home about" (R8)* - *"Government should provide loans..." (R12)* - *"Some of the teachings... are very complicated" (R5)*	**Innovation Diffusion Theory** – complexity as a barrier. **Social Learning Theory** – peers and simplicity enhance adoption. **Systems Theory** – highlights financial, institutional, and ecological constraints.	3–4

Source: Authors' Construct

Table 1 provides a summary of the key themes explored in the interviews, the guiding questions, illustrative farmer quotes, and their theoretical linkages. The themes include farmers' perceptions and satisfaction with extension delivery methods, the types of sustainable land use practices promoted, and the barriers and facilitators to adoption. The table also demonstrates how each theme is connected to the four theoretical perspectives: Participatory Extension Theory, Social Learning Theory, Innovation Diffusion Theory, and Systems Theory, thereby linking farmers' lived experiences to broader conceptual frameworks.

4. Results and discussion

Table 2: Demographic characteristics of farmers (n = 20)

Characteristic	Category	Frequency	Percent (%)
Gender	Male	12	60.0
	Female	8	40.0
Age Group	20–35 years	5	25.0
	36–50 years	9	45.0
	51 years and above	6	30.0
Farm Size	Small (<2 acres)	8	40.0
	Medium (2–5 acres)	7	35.0
	Large (>5 acres)	5	25.0

Source: Field Data, 2025

Table 2 summarises the demographic characteristics of the 20 farmers who participated in the study. The sample was fairly gender-balanced, with males forming 60% and females 40%. Most farmers (45%) were in the 36–50 age group, while 25% were aged 20–35 years and 30% were above 51 years. In terms of farm size, 40% cultivated small farms of less than 2 acres, 35% managed medium farms (2–5 acres), and 25% operated larger farms exceeding 5 acres. These characteristics reflect a diverse but predominantly middle-aged farming population with varying scales of landholding.

Table 3: Categories of key informants (n = 8)

Category	Frequency	Percent (%)
Agricultural Extension Officers	3	37.5
Traditional Leader	1	12.5
Farmer-Based Organisation Rep.	1	12.5
Input Dealer	1	12.5
NGO Representative	1	12.5
Lead Farmer / Opinion Leader	1	12.5
Total	8	100.0

Source: Field Data, 2025

Table 3 presents the categories of the eight key informants who provided expert insights to complement farmers' perspectives. Agricultural

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extension officers made up the largest group (37.5%), while the remaining categories, traditional leader, farmer-based organisation representative, input dealer, NGO representative, and lead farmer/ opinion leader, each accounted for 12.5%. This diversity of informants ensured that multiple institutional and community perspectives were represented in the study.

4.1. Farmers' perceptions and satisfaction levels with current extension service delivery methods in promoting sustainable land use practices

Table 4: Farmers' attitudes towards extension service delivery methods

Attitude category	Frequency (n)	Percent (%)
Satisfied	13	65
Neutral	3	15
Dissatisfied	4	20

Source: Field Data, 2025

NB: *Satisfied* – Farmers expressed approval of one or more delivery methods; *Neutral* – Farmers had no specific preference but welcomed available methods; *Dissatisfied* – Farmers expressed challenges or discontent with certain methods (e.g., lack of interaction on radio, disruptions during group meetings).

Out of the 20 farmers who participated in the focus group discussions, the majority (65%) expressed satisfaction with extension service delivery methods used in promoting sustainable land use practices, while 15% remained neutral and 20% expressed dissatisfaction (Table 4). Generally, the results illustrate that extension delivery methods in Fanteakwa South Municipality are broadly valued, but no single method is without limitations. The diversity of farmer responses suggests that a pluralistic approach combining group meetings, community information centres, radio programmes, and home visits is most effective. This aligns with Oyetunde-Usman et al. (2020), who stressed the importance of varied and responsive extension strategies to meet the diverse needs of smallholder farmers in addressing agricultural challenges. The findings also reflect principles of systems theory, which emphasize that effective extension must integrate multiple communication channels to address the varied socio-ecological and institutional contexts within which farmers operate (Hameed & Sawicka, 2023).

Farmers who expressed satisfaction highlighted the usefulness of group meetings, radio programmes, home visits, and community information centres. For example, one farmer explained: "*My extension officer uses various methods in delivering his messages to us. To me, the group method is the best way I receive extension delivery messages regarding sustainable land use practices.*" This appreciation for group methods reflects Molina et al.'s (2021) conclusion that group meetings foster interaction and collective learning, allowing farmers to share experiences and deepen their understanding of sustainable practices. It also connects with social learning theory, which posits that farmers learn more effectively through observation of peers, group problem-solving, and reinforcement within a social context (Yang et al., 2024). By engaging in groups, farmers not only receive information but also validate its usefulness through the shared experiences of others.

Similarly, another farmer remarked: "*The community information centre used to spread information is very good. I see it as one of the best methods. The local language is used, and it is normally done early mornings and evenings. Most of the farmers are around during this period; thus, they get every relevant information needed in promoting sustainable land use practices.*" This supports the work of Alakpa and Ehigie (2024), who noted that community information centres are most effective when communication is delivered in local languages and at times convenient for farmers. From the perspective of participatory extension theory, this example shows that tailoring messages to farmers' linguistic and cultural contexts enhances ownership and co-creation of knowledge. Rather than top-down transfer, farmers perceive the information as embedded in their realities, making it easier to apply in practice.

Radio was also praised for its wide reach. As one farmer noted, "*The radio is the one I prefer. It can reach a lot of people at the same time. There is a program on the radio on Fridays that addresses challenges farmers go through. They also talk about ways we can practice sustainable land use by farmers.*" The broad reach of radio programmes has similarly been documented in studies (Molina et al., 2021), which highlight their ability to reach large audiences with relevant messages. From an

innovation diffusion perspective, radio functions as a platform for enhancing observability, one of Rogers' key attributes of adoption, by making new practices widely visible and accessible to large numbers of farmers. However, as later findings show, the limited interactivity of radio restricts *trialability* and *feedback loops*, thereby constraining adoption.

Likewise, personalised extension methods were valued, with one farmer noting: "*When the farmers are visited in their homes and farms, it helps a lot. We get the opportunity to ask questions. This approach is very helpful.*" This mirrors the observations of Alakpa and Ehigie (2024), who found that home visits foster trust and allow for clarification, enhancing farmers' learning experience. In theoretical terms, home visits exemplify the facilitator role described in participatory extension theory, where extension agents act as co-learners who adapt knowledge to farmers' circumstances rather than imposing pre-packaged solutions. They also embody the change agent role in innovation diffusion theory, as effective adoption depends on the interpersonal trust and cultural sensitivity extension officers bring to their interactions.

Neutral respondents (15%) demonstrated flexibility, as captured in the statement: "*I welcome what is available to help me with my farming and having information on sustainable land use practices within our community.*" This neutral stance suggests that while these farmers do not strongly prefer a particular method, they remain open to the available channels. Tham-Agyekum et al. (2024) also argue that the effectiveness of extension delivery can vary across individuals, depending on their priorities, circumstances, and level of access. Neutral responses illustrate the systems perspective, where adoption outcomes are not solely determined by extension strategies but also by the interaction of household resources, institutional arrangements, and broader socio-economic dynamics.

By contrast, 20% of farmers expressed dissatisfaction, particularly with radio and group methods. One farmer explained: "*The radio is not the best at all. Well, though it can reach a lot of people at the same time, farmers cannot ask questions when needed. Sometimes I want to ask questions, but it is always difficult. They allow listeners to call, but I have never had the chance to speak to them. It has been my problem all this time.*" This concern is echoed in Molina et al. (2021), who reported that the one-way communication format of radio limits opportunities for engagement and immediate clarification. From the lens of participatory extension theory, such dissatisfaction highlights the limitations of linear, top-down communication models that fail to create spaces for dialogue and co-learning. Another farmer added, "*The group method is not all that helpful. There are always farmers causing problems at meetings, disrupting the extension agent's effort to disseminate information to us. Others act in an intimidating manner, preventing others from asking relevant questions.*" These challenges reflect broader concerns in the literature that group meetings, while beneficial for collective learning, can sometimes be undermined by group dynamics and dominance issues. In terms of social learning theory, this suggests that not all group environments foster positive learning; peer influence can also create negative dynamics if dominant individuals inhibit participation. From a systems perspective, such challenges demonstrate that extension delivery cannot be divorced from the social structures and power relations that shape community interactions.

4.2. Types of sustainable land use practices promoted by extension agents

Table 5: Types of Sustainable land use practices promoted by extension agents

Sustainable practice	Number of farmers (n=20)	Percent (%)
Soil fertility management	17	85
Crop rotation/intercropping	14	70
Erosion control	11	55
Agroforestry	10	50
Water conservation	8	40
Integrated pest management	7	35

Source: Field data, 2025

The findings revealed that extension agents in Fanteakwa South Municipality actively promoted a diverse range of sustainable land use practices. Out of the 20 farmers who participated in focus group discussions, soil fertility management (85%) emerged as the most emphasised practice, followed by crop rotation/intercropping (70%), erosion control (55%), agroforestry (50%), water conservation (40%), and integrated pest management (35%). These

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results align with Yeboah (2021) and Quayson and Kwadzo (2021), who emphasise that farmers in Ghana and other parts of Africa are increasingly adopting integrated soil fertility management and indigenous land management techniques as viable approaches to sustainable agriculture. The range of practices reflects the logic of systems theory, which stresses that sustainable land management requires a holistic set of interventions rather than isolated actions. By promoting multiple practices, extension agents encourage farmers to address soil fertility, water, biodiversity, and pest control in an integrated manner.

Farmers consistently highlighted soil fertility management practices such as composting, mulching, and the judicious use of organic manure. One farmer explained: "The officers encouraged us to use compost instead of relying too much on chemical fertiliser. They even showed us how to prepare it with crop residues and animal droppings, and I have tried it on my maize farm". This observation resonates with Quayson and Kwadzo (2021) and Yeboah (2021), who found that farmers in semi-arid Ghana widely recognise composting and animal manure as effective strategies for maintaining soil fertility. The popularity of composting illustrates innovation diffusion theory's concept of relative advantage, as farmers see it as a cheaper and more sustainable alternative to chemical fertilisers. At the same time, the practical training by extension agents reflects participatory extension theory, where farmers are not passive recipients but active co-learners in knowledge application.

Agroforestry was also frequently promoted, with farmers reporting sensitisation to planting shade trees on farms to prevent soil degradation and maintain biodiversity. One participant shared: "We were told to plant trees among our cocoa so that the land does not lose its strength. Before, I used to cut down all the trees, but now I leave some of them". The promotion of agroforestry echoes findings by Lahmar et al. (2012), who noted that integrating trees into farming systems enhances resilience and long-term soil health. This shift demonstrates social learning theory, as farmers change their behaviour after observing both the ecological benefits and the collective uptake of agroforestry in their communities. It also resonates with systems theory, since trees interact with soils, crops, and microclimates, producing multiple benefits across the farming system.

Crop rotation and intercropping were identified by 70% of farmers as strategies for improving soil health and reducing pest infestations. As one farmer stated: "The extension people told us not to plant maize on the same land every year. I tried groundnut after maize, and the harvest was better the following season". This supports existing evidence that rotating maize with legumes enhances nitrogen fixation and improves yields (Quayson and Kwadzo, 2021). The fact that farmers experiment with different crop sequences reflects innovation diffusion theory's trialability and observability, as they can test the practice on a small scale and observe results within one season. It also reflects participatory extension principles, as extension officers and farmers work together to adapt rotations to local conditions rather than prescribing a one-size-fits-all solution (Lahmar et al., 2012).

Erosion control measures were mentioned by more than half (55%) of the farmers, who had adopted contour ploughing and cover cropping. A farmer noted: "They showed us how to make ridges across the slope. I did it on my cassava farm, and I realised the rain did not wash away the soil like before". These findings underscore the role of extension in improving awareness of soil conservation practices, which are critical in addressing the challenges of land degradation in Ghana. Adoption of such measures reflects social learning theory, as farmers gain confidence when they witness visible outcomes on their own or neighbours' farms. Moreover, from a systems perspective, erosion control practices have wider environmental benefits beyond individual plots, including watershed protection and reduced downstream flooding (Firoozi & Firoozi, 2024).

Water conservation practices, although promoted, were adopted by only 40% of farmers. Simple techniques such as rainwater harvesting and small-scale irrigation were discussed, though adoption was limited by financial constraints. As one respondent explained: "They talked about water harvesting, but it is not easy for us to get tanks. Some of us use barrels to collect rainwater, but it is not enough". This reflects the fact that financial barriers often limit the uptake of water-saving technologies, even when farmers understand their benefits. Low adoption here is explained by innovation diffusion theory's compatibility and complexity dimensions: although farmers appreciate the benefits, the practice is costly and technically demanding in

relation to their resources. A participatory extension approach could help bridge this gap by identifying low-cost, community-driven alternatives that fit farmers' realities.

Finally, integrated pest management (IPM) was promoted to a smaller extent (35%), particularly as part of broader training on sustainable land use. Farmers acknowledged that while IPM reduces reliance on chemical pesticides, adoption remained low due to limited access to biological control inputs and knowledge gaps. The limited uptake illustrates innovation diffusion theory, as IPM tends to score low on trialability and observability compared to simpler practices like mulching or crop rotation. From a social learning perspective, the lack of visible peer demonstrations reduces confidence in IPM. This is where participatory extension becomes vital, since collaborative experimentation and farmer field schools could bridge the knowledge gap and make IPM practices more accessible (Tham-Agyekum et al., 2025).

4.3. Barriers to the adoption of sustainable land use practices

Table 6: Barriers to adoption of Sustainable land use practices as reported by farmers

Barrier	Frequency	Percent (%)
Financial constraints (input costs)	9	45.0
Limited access to credit facilities	6	30.0
Complexity of extension messages	5	25.0

Source: Field Data, 2025

A central barrier identified by farmers was limited financial capacity to invest in sustainable land use practices. Several participants noted that the cost of farming inputs remained a major impediment: "I would love to adopt these sustainable land use practices, but I don't have the money to buy farming inputs to help me. I lack the financial power. This has hampered my farming over the years". Similarly, another farmer observed: "The incentives given by the authorities are not enough. But, because of money issues, I can only buy a few to support my farming practices for sustainable land usage". These sentiments reflect the broader economic reality of smallholder farmers, who operate on limited resources and struggle to meet the upfront costs associated with improved practices. One farmer explained: "We do peasant farming in this area. Our harvest for the year is nothing to write home about. Hence, making enough money to buy items and maintain sustainable land use practices. The initial investment costs for transitioning to sustainable land use practices often exceed the immediate financial capacity of smallholder farmers, creating a significant adoption gap". Similar findings are reported in other contexts, where high input costs and limited profitability act as deterrents to adoption (Kaine & Wright, 2022).

From the lens of innovation diffusion theory, these financial limitations reduce the perceived relative advantage of adopting new practices. Even when farmers recognise the long-term benefits, the high upfront costs make them appear less attractive compared to conventional methods. At the same time, systems theory reminds us that adoption barriers are not purely individual challenges but arise from structural weaknesses in the farming and financial systems. Without interventions that address credit, input supply, and market access simultaneously, farmers' capacity to adopt sustainable land use practices will remain constrained (Gregg, 2021).

Closely linked to financial limitations is the restricted access to credit facilities. Farmers emphasised the importance of financial support mechanisms that could enable them to procure inputs: "I think the government should provide loans for the farmers so they can have access to some of the farm inputs". Another farmer added: "We need some economic relief so farmers can have access to credit facilities". This finding aligns with broader evidence that inadequate access to rural credit remains a structural constraint in developing countries, as collateral requirements, cumbersome loan conditions, and high interest rates frequently exclude smallholders from formal financial systems. Consequently, without improved financial inclusion, the capacity of farmers to embrace sustainable practices will remain limited. From a participatory extension perspective, this calls for the design of farmer-centred financial innovations, such as cooperative credit schemes or savings groups, that can be developed with farmer input and ownership. When farmers are involved in shaping such mechanisms, the likelihood of uptake and sustainability increases.

Another key barrier was the complexity of extension messages and technical recommendations. Some farmers described difficulties in comprehending the information provided by extension officers:

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"Some of the teachings by the extension agents are very complicated. I don't understand some of the things they say, making the adoption of some of the sustainable land use practices very difficult. I sometimes improvised to make sure I am doing the right thing in connection with sustainable land use practices". This reveals a disconnect between the technical framing of extension messages and the realities of farmers' knowledge systems and capacities. Similar concerns have been raised in studies that highlight how the effectiveness of extension is undermined when messages are not simplified or contextualised for end-users (Alakpa & Ehigie, 2024; Oyetunde-Usman, 2020).

The improvisation by farmers indicates adaptive resilience but also underscores the need for extension agents to employ social learning approaches, where farmers learn together through observation, discussion, and mutual problem-solving rather than top-down instruction. When farmers observe peers successfully applying simplified practices, their confidence in trying the same increases, which reinforces innovation diffusion through trialability and observability. Finally, through the lens of systems theory, these communication challenges highlight that technical knowledge, farmer literacy levels, and cultural contexts are interconnected parts of the agricultural knowledge system. Effective adoption, therefore, requires interventions that bridge these gaps in a coordinated way.

5. Conclusion

The study set out to examine farmers' experiences with extension services in promoting sustainable land use practices in the Fanteakwa South Municipality. The findings showed that farmers accessed extension information through diverse channels, including farm visits, group meetings, community information centers, and radio programs. While interactive methods such as farm visits and group demonstrations were praised for their practical value, some farmers expressed dissatisfaction with radio programs because they provided limited opportunities for direct interaction and feedback.

Barriers to adoption included financial limitations, lack of access to credit, and the technical complexity of extension messages. Farmers often lacked the resources to purchase the inputs required to implement recommended practices, and some struggled to fully understand the technical language used by extension officers. On the other hand, adoption was facilitated by trust in extension officers, peer-to-peer learning, practical demonstrations, and support mechanisms such as subsidies and input supply. Farmers further emphasized the importance of participatory methods that recognize their indigenous knowledge and local farming realities.

The findings highlight the need for extension services to prioritize farmer-centered approaches that go beyond knowledge transfer. Extension officers must develop strong facilitation and communication skills, including the use of local languages and context-appropriate examples, to make technical recommendations more accessible. At the same time, the results show that economic constraints remain a critical barrier, suggesting that extension services should be integrated with financial support mechanisms such as input subsidies, microcredit schemes, and market access facilitation. Moreover, the multiplicity of actors involved in extension delivery underscores the importance of collaboration and coordination to avoid mixed messages and to build a more coherent extension system.

The study recommends the creation of a coordinated farmer-centered extension platform that unites key stakeholders to deliver consistent messages, integrate local knowledge with scientific advice, and provide practical support to enhance the adoption of sustainable land use practices.

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Impact of Climate Change on Bitter Honey in Chattogram Mangrove Forest Area: An Exploratory Study

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Abstract:

Bitter honey, a unique product of Bangladesh, is under serious threat of extinction, primarily due to climate change. This study explores the impact of climate change on the production, quality, and quantity of bitter honey using qualitative methods. This study employed a qualitative, non-probability data collection method to interview honey collectors and honey sellers. A total of 10 in-depth interviews identified several factors directly related to climate change. Bitter honey, produced in August from the pollen of Gewa, Neem, Bitter Gourd, Minjori, Boroi, and Koroi trees, has seen a sharp decline in production. Excessive rainfall, flash floods, reduced floral growth and resources, increased honeybee mortality, premature hive cutting, and Deforestation are the key factors in this decline. Particularly, excessive rainfall disrupts honey collection and damages hives, while high heat kills bees and larvae. In previous years, collectors could harvest up to 14 kg per hive, which has now fallen to 2-3 kg. Deforestation for the establishment of industrial zones in Mirsharai and Sitakundo has further threatened honey production by destroying floral resources and bee habitats. The study emphasizes the urgent need for a comprehensive policy to protect both the production of bitter honey and the ecosystem in the Chattogram mangrove. Awareness among the public, government, and all stakeholders is crucial to preventing climate change issues in this region. These issues not only affect honey production but also endanger the whole ecosystem.

Keywords: Bitter honey, Climate change, Mangrove forest, Honeybee, Deforestation.

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1. Introduction

Honey is commonly perceived as a sweet liquid used to enhance the flavor of food and as a natural remedy due to its antioxidant properties, which help combat various diseases in both humans and animals. Its sweet, sticky texture makes it versatile. However, it may come as a surprise that bitter honey also exists and is often valued even more highly for its medicinal properties. In certain regions around the world, bitter honey is produced, collected, and even sold at a premium, surpassing the price of regular sweet honey.

The bitter honey named ***Corbezzolo*** (strawberry tree in Italian) **honey**, produced in Sardinia, Italy, is renowned worldwide for its premium quality and is exported to various regions across the globe. A popular saying about Sardinia reflects its distinctiveness: 'Sardinia was a harsh island; everything on the island was unappealing, and even its abundant honey was bitter' (Ulloa et al., 2015). This unique type of honey can also be found in the Sierra de Monchique in Portugal, Indonesia, and several regions of Africa and Asia. The characteristic bitterness of this honey primarily derives from the pollen collected by bees from the flowers of the strawberry tree (Floris et al., 2021). This honey is highly valued for its extensive nutritional benefits and is regarded as the ultimate remedy on Sardinia Island (Rosa et al., 2011). It is rich in vitamins, minerals, and anti-inflammatory compounds. It has been cherished for generations on an island famous for the exceptionally long lives of its residents, many of whom live well past 100 years (Vallianou, 2014). Honey extracted from the strawberry tree flower also contains nutrients that help prevent colon cancer (Afrin et al., 2019).

This type of honey is also found in various regions across Asia and Africa. In the mangrove forests of Borneo, located in the Loksado area of South Kalimantan and on Bangka Belitung Island in Indonesia, there are specific areas where bitter honey is harvested. Local communities have been collecting this honey for generations. The bitter honey, derived from Sungkai flowers, is noted for its anti-diabetic and anti-inflammatory properties (Hamidah et al., 2019). Furthermore, according to Otmani et al. (2019), the bitter unifloral honey from the Mediterranean coast of Algeria exhibits more potent antioxidant properties than the sweet polyfloral honey from the same region.

Bitter honey is also produced in the southeastern mangrove forests of Bangladesh, particularly in the Mirsharai area of Chattogram. Local communities have been collecting this natural, bitter honey from the mangroves near the Bay of Bengal for generations. The honey here is primarily derived from the Gewa trees in the forest. A single comb can be harvested three times within one season, with some extending to four or five extractions. Typically, 20 to 30 kilograms of honey are harvested at a time, with potential yields reaching up to 40 kilograms. It is highly valued for its medicinal properties and is particularly popular among consumers with diabetes (Stefanis et al., 2023; Lazaridis et al., 2024).

The climate in the coastal areas of the Bay of Bengal has been severely impacted by climate change over the years. The production of bitter honey also decreased in quantity, and there is a risk that this bitter honey could become extinct in the near future (Awulachew, 2025; Gajardo-Rojas et al., 2022). However, this issue has received limited research attention and advocacy focus. Focusing on this risk can provide us with the insight we need into this issue, and possibilities for a way forward to save this unique and priceless delicacy unfold.

Figure 1: Study area (Village, Mangroves, and Coastline) – Google Earth.

2. Literature review

Research has identified bitter honey in Algeria, Indonesia, Italy, and Bangladesh (see Table 1) (Daniyan et al., 2024; Floris et al., 2021; Hamidah et al., 2019; Otmani et al., 2019; Olas, 2020). According to every piece of literature found on bitter honey, it explains that this honey is more nutritious than the sweet ones. However, climate change is negatively affecting the production, collection, and taste of this honey.

Table 1: Comparison of global studies on Bitter Honey

Study location	Threats	Key findings	Sources
Sardinia, Italy	Declining production linked to rising temperatures in Sardinia.	Strawberry-tree (*Corbezzolo*) bitter honey is renowned for its rich antioxidant and medicinal compounds.	(Floris et al., 2021)
Indonesia	Declining production is connected to excessive rainfall and extreme heat.	Bitter honey from *Sungkai* flower has anti-diabetic and anti-inflammatory properties.	(Hamidah et al., 2019)
Algeria (Mediterranean coast)	Declining production is connected to premature harvesting and extreme heat.	Unifloral bitter honey from the Algerian Mediterranean coast shows stronger antioxidant properties than local polyfloral honey.	(Otmani et al., 2019)
Mirsharai mangroves, Bangladesh	Declining production is connected to excessive rainfall, floods, heat, premature harvesting, and Deforestation.	Bitter honey in Mirsharai is produced from mangrove flowers, which are valued medicinally, but there have been recent sharp declines in quantity and quality.	(Chowdhury, 2025)

2.1. Threat of climate change

Current issues of climate change may put honeybees' lives at risk and lead to the extinction of some rare honey harvests. There are serious problems with honey production and collection that can be caused by climate change. Both the honey production and the lives of honeybees are in danger. The honey collectors in Bangladesh's Sundarban are very concerned about their next generation and whether they can continue this profession. The production of honey has been declining over the past few years, which concerns honey collectors (Chowdhury, 2025; Mahankuda & Tiwari, 2024).

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2.2. Impact of climate change on the lives of honeybees

Bees, particularly honeybees, are facing an existential threat. The effects of climate change have manifested globally, with rising temperatures serving as a key indicator. In the first half of this year, humanity experienced an unprecedented heatwave worldwide, signaling that 2024 is set to become the hottest year on record, surpassing previous temperature records (Sangomla, 2024).

Neumann and Straub (2023) highlighted threats posed by rising temperatures to honeybee populations. Extreme heat significantly shortens their lifespan, often leading to colony losses within honey hives. While particular bee species have shown adaptability to climate change, prolonged exposure to extreme conditions can diminish their resilience. Also, the growing impact of pests and the increasingly frequent seasonal shifts force bees to migrate to new regions in search of more favorable conditions (Quinlan et al., 2023). Increased temperature impacts the spring migration of honeybees. Moreover, hive damage, pest aggression, thermal stress, and increased resistance collectively contribute to shorter lifespans within bee colonies (Abou-Shaara, 2016; Landaverde et al., 2023; Lanoix, 2021).

Bees' diseases can be caused by mites, protozoa, bacteria, viruses, and other parasites. The flowers can save water, which can be used by bees (Mensah et al., 2016). But when the flowers can't save any water in extreme heat or in deserts, it is more likely to lead to the death of bees in those areas. Shortages of food in dry climates lead to poor nutritional quality in honeybees. In extreme conditions, when bees must adjust their behaviour, they lose some of their genetic diversity and enter into competition, leading to ecological imbalances. Overall, this impact leads to high honeybee mortality rates (Conte & Navajas, 2008).

2.3. Impact of climate change on the taste and existence of honey

Global honey production has been declining in recent years, primarily driven by climate change. Extreme heat and natural disasters are causing widespread agricultural failures and forest destruction, leading to reduced flower production and a lack of floral resources for bees, which impacts pollination rates (Neumann & Straub, 2023). Moreover, shifting land-use patterns and extreme cold weather are reducing soil productivity, further limiting floral growth. As a result, honeybees are forced to migrate to warmer regions, contributing to the overall decline in honey production (Lanoix, 2021; Quinlan et al., 2023).

In certain regions, heavy rainfall washes away flowers and their pollen, making them less attractive to honeybees. The absence or shortage of pollen forces bees to migrate in search of more abundant floral resources, ultimately leading to a decline in honey production in affected areas and increased honeybee mortality. Also, the quality of honey has diminished as some flower species have disappeared (Conte & Navajas, 2008).

The Sundarbans mangrove forest in Bangladesh has such rich resources for honey production. However, honey production and harvesting in the forest have been declining over the past few years (Roy and Hossain, 2015; Mukhopadhyay et al., 2018). Many people rely solely on honey harvesting as their livelihood, but extreme weather in Bangladesh has severely affected honeybee birth, growth, and honey production in this region. There is a growing risk that future generations may no longer be able to harvest honey from the Sundarbans. Many honey harvesters have already abandoned the profession and moved to the capital city in search of alternative sources of income (Chowdhury, 2025; Mahankuda & Tiwari, 2024).

2.4. A way forward

Honey production and harvesting play a crucial role in maintaining ecological balance by promoting pollination, which supports the reproduction of various plant species. This process is essential for environmental conservation, economic growth, food security, and addressing health and social issues. To sustain these benefits, it's crucial to preserve honey and prevent its decline. Key actions include planting trees, boosting floral productivity, and reducing carbon emissions. Moreover, combating climate change and global warming is vital to safeguard both the existence and quality of honey (Koech et al., 2023).

Bitter honey, a rare delicacy found in the mangrove forests of Mirsharai, Chattogram, Bangladesh, faces the risk of extinction, much like other honey varieties in Bangladesh. Intensive urbanization and industrialization in the region have led to

Deforestation and rising temperatures, threatening this unique and rare species of honey (Hossain et al., 2024). Therefore, it is crucial to explore and address the potential threats to preserve this rare and valuable resource.

2.5. Research gap and significance of this study

Extensive research has been conducted on several issues and prospects related to climate change. In Bangladesh, numerous studies examined climate challenges and proposed numerous mitigation strategies. However, research focusing on the threat of extinction and the declining quality of unique delicacies is limited. Although some studies have addressed these issues in their specific contexts, this area remains largely unexplored in Bangladesh. With the ongoing effects of climate change, the threat of extinction for many traditional delicacies continues to grow. One such delicacy is the bitter honey from the mangrove forests of Bangladesh, which is at risk of losing both its existence and quality due to various climate-related factors that urgently require attention. This study investigates the impact of climate change on bitter honey. By exploring this issue, this research aims to uncover the causes and consequences of climate change on bitter honey, with findings that can raise awareness among stakeholders and the public about the broader impacts of climate change on this unique delicacy.

The objective of this study is to assess the impact of climate change on the existence and flavor of "Bitter Honey." Specifically, the research seeks to explore whether there are any threats affecting the existence and taste of bitter honey in the mangrove forest of Mirsharai, Chattogram, to identify and understand how climate change influences the mangrove forest and bee populations, and to examine whether such changes directly affect the existence and flavor of this unique honey.

3. Method

This research follows a qualitative research approach to explore the existential threat and changing taste of bitter honey. The study area includes the mangrove forests in Mirsharai and Sitakundo in Chattogram District, which include *Moghadia* Mangrove Forest, *Saherkhali* Mangrove Forest, *Domkahli* Mangrove Forest, *and Bogachatar* Mangrove Forest (see figure 1). The population of this study comprises honey collectors who harvest honey from these mangroves and honey sellers in this region. There are only a few collectors and sellers of this unique delicacy in Bangladesh. Only seven individuals who collect bitter honey were found across the entire mangrove forest area, and only three (03) shops were found where they do research and sell the bitter honey (see Table 2 for sociodemographic information of respondents). A non-probability convenience sampling method was used to select the respondents. In-depth interviews were conducted with 10 respondents through a semi-structured interview guide, which included seven honey collectors and three honey sellers. Also, the researcher made observations during data collection to gain a comprehensive understanding of this issue. Once the researchers reached data saturation, the data were systematically coded using open and axial coding, and some categories emerged. All coding processes were conducted by the authors based on the recordings and the transcript. No software is used for this process. The coding framework for this study began with open coding using specific keywords from the transcript, followed by axial coding to develop categories. Subsequently, several sub-themes were identified, which ultimately resulted in the emergence of core themes. Finally, the findings were presented thematically. A small number of people from the local communities in the mangroves collect and sell this honey, but there are growing concerns about its potential extinction, as honey production has been declining over the years. This reduction, along with potential changes in honey's flavor, may be linked to climate change. To achieve a holistic outcome from this study, interviews with honey collectors and sellers provide valuable insights into the flavor changes and the existential threat to bitter honey, possibly tied to climate change.

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Table 2: Sociodemographic information of respondents

Sociodemographic Information	Frequency (n)	Percentage (%)
Involvement with Bitter Honey		
Collector	7	70%
Seller	3	30%
Gender		
Male	10	100%
Age		
25-34 Years	3	30%
35-44 Years	3	30%
45-54 Years	3	30%
55-65 Years	1	10%
Experience in collecting/selling Bitter Honey		
1-5 Years	5	50%
6-10 Years	1	10%
11-15 Years	3	30%
16-20 Years	1	10%
Village		
Domkhali, Mirsharai, Chattogram	2	20%
Bogachotor, Sitakundo, Chattogram	5	50%
Mirsharai Municipality, Mirsharai, Chattogram	2	20%
Chattogram City Corporation, Chattogram	1	10%
Total	**10**	**100%**

BRAC ethically approved this research, and all the respondents verbally consented to participate in this research. All these interviews were conducted in the *Domkahli* and *Bogachatar* Mangrove Forest area in September and October 2024. Each of these interviews has taken approximately 40 to 50 minutes to complete (see figure 2-7 for graphical details). All interviews were conducted in Bengali and recorded with the respondents' verbal consent. The interviews were then transcribed and translated by the authors.

Figure 2: Hive of Bitter Honey (Location: Bogachotor).

Figure 3: Into the Mangroves (Location: Domkhali).

Figure 4: The Minjiri Tree (Location: Domkhali).

Figure 5: Office of Forest Officer (Location: Domkhali).

Figure 6: The Construction of a New Road through Deforestation (Location: Bogachotor).

Figure 7: The Entrance Path of Village with Bitter Honey (Location: Bogachotor).

4. Findings and Analysis

The data for this study were collected through in-depth interviews with respondents using a semi-structured interview guide (see Appendix 1). Subsequently, the data were coded, categorized, and subjected to thematic analysis to obtain a comprehensive understanding of the status, future prospects, and threat of extinction of bitter honey, as well as the relationship between climate change and bitter honey.

4.1. Overview of bitter honey in Bangladesh

Bitter honey is a unique delicacy found exclusively in certain areas, including parts of Bangladesh, particularly mangrove forests. This honey is produced from the nectar of certain mangrove flowers, which contain a bitter essence but attract honeybees with their distinctive fragrances. This process results in the production of bitter honey. As a honey collector said:

> *"Since bees collect nectar from various flowers, the honey can sometimes taste bitter, while other honeys might be sour or a mix of sweet and sour. It is impossible to predict when these types of honey will be produced, as the flavor is determined by the specific flowers the bees visit. When bees gather nectar from Gewa and Neem flowers, for example, the honey becomes bitter." (Md. Islam, Honey Collector)*

This bitter honey contains no sugar or sucrose, which makes it particularly popular among individuals who are unable to consume sugar, such as those with diabetes or high blood pressure. As one honey collector noted:

> *"Bitter honey, in particular, has numerous nutritional benefits that many people are unaware of. Some individuals have difficulty consuming regular honey, but they can easily tolerate bitter honey without issues." (Md. Selim, Honey Seller)*

This honey can only be produced in mangrove forests, as the trees with flowers containing bitter nectar are found there. Also, the honeybee species that produces this honey, Apis dorsata, cannot be domesticated and is found only in forest environments. A honey seller further explained:

> *"The Apis dorsata bee produces this type of honey, but it cannot be domesticated, so this honey cannot be cultivated in artificial environments. It is only available in forests, particularly in saline and mangrove regions, where both the Apis dorsata bee and Gewa trees coexist." (Md. Shahin, Honey Seller)*

This observation demonstrates that *Apis dorsata* bees are non-selective pollinators, collecting nectar based on scent rather than flavor preference, which explains the variety of honey flavors produced from the same forest area.

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4.2. Place & time of getting bitter honey

The primary source of this honey is the Gewa tree, which grows in mangrove forests. The tree's flowers typically blossom in August, making this the key period for bitter honey production. As one seller remarked:

> *"The honey from the Gewa blossoms has a bitter taste—though not overly bitter, it is not sweet at all. This honey is typically harvested in August and is particularly beneficial for individuals with diabetes or those with dietary restrictions on sugar." (Md. Shahin, Honey Seller)*

Bitterness can also be present in other types of honey, as honeybees are unable to distinguish between different flowers. As a result, traces of bitter honey may be found in other varieties. As one seller explained:

> *"This honey is harvested from trees that thrive in saline areas, and its distinct bitterness comes from the flowers of the Gewa tree. Since bees collect nectar from a variety of flowers, traces of bitterness may also be found in other honeys." (Md. Shahin, Honey Seller)*

In Bangladesh, most flowers bloom during the spring season, which falls in the months of Chaitra and Baishakh (March, April, May). Consequently, honey production during this period is significantly higher compared to other months. As one collector noted:

> *"The months of Chaitra and Baishakh are the best time for honey collection, as new flowers bloom, and honey production is optimal in summer." (Md. Rezvi, Honey Collector)*

4.3. Cause of bitterness in bitter honey

In the mangroves of Mirsharai and Sitakundo, six different varieties of honey can be found. These varieties encompass sweet, bitter, sour, and hybrid combinations of these flavors. As one honey collector suggests:

> *"I have been collecting honey for about eight years. In our forest, we have six different types of honey. One is very sweet, another is slightly salty and sweet, one is bitter, another is bittersweet, there's a kind that comes from new flowers, then there's sour-sweet honey, and finally, there's purely sour honey." (Md. Akbor Hosen, Honey Collector)*

In summary, the types of honey found in the Mangrove at Mirsharai and Sitakundo are as follows in Table 3:

Table 3: Types of Honey found at Mangrove at Mirsharai and Sitakundo

Type	Taste
Type 1	Sweet
Type 2	A mix of slightly salty and sweet taste
Type 3	Bitter
Type 4	Bittersweet
Type 5	A mix of sour and sweet tastes
Type 6	Sour

Bitter honey derives its distinctively bitter taste from a variety of flowers, including those of the Gewa tree, bitter gourd, and Neem tree. As the harvester explains:

> *"Bitter honey comes from flowering plants like bitter gourd, Neem, and Gewa. The honey from the Gewa tree is particularly bitter, as its flowers have a pleasant smell but produce honey with a bitter taste. Bees are unable to distinguish the flavor, so they collect the nectar based on the scent, resulting in bitter honey." (Md. Nurul Haque, Honey Collector)*

The honey gradually transitions from sweet to bitter, then finally sour during the final period of the year. Initially, the honey is purely sweet, but over time, it acquires a bitter note, influenced by the blossoms of the *Jamgach, Barai, Koroi,* and *Minjiri* flowers, ultimately turning sour. As one collector posits:

> *"The first collection (in a season) yields sweet honey; the second tends to be bitter, or bittersweet; and by the final harvest, the honey has a slightly sour taste. The flavor entirely depends on the flowers in bloom. Towards the end of the season, flowers from trees like Jamgach, Barai, Koroi, and Minjiri contribute to the production of bitter honey." (Md. Mostofa, Honey Collector)*

4.4. Demand for bitter honey

The demand for bitter honey is comparatively lower than that of other types of honey. The most popular honey in Bangladesh comes from the blossoms of the Khalisha flowers in the Sundarbans. Despite offering superior nutritional value, bitter honey has not achieved the same level of popularity. As one seller said:

> *"The bitter honey available in Mirsarai is rarely stocked, as demand for it is comparatively lower, primarily purchased by individuals with diabetes. Honey from the Khalisha and mustard flowers remains in high demand." (Md. Shuvo, Honey Seller)*

The lack of demand is primarily due to insufficient marketing and promotion of bitter honey. Other varieties of honey have received so much attention that bitter honey has consistently lost its markets. As one seller explained:

> *"Many people are unaware of the benefits of this bitter honey, as it has not been widely promoted. In our shop, we offer honey at prices ranging from 600 to 2000 taka, depending on the floral source. The bitter honey from Gewa flowers is sold at 1000 taka per kilogram." (Md. Shahin, Honey Seller)*

4.5. Relation of bitter honey with climate change issues

Recent climate challenges, including excessive heatwaves, heavy rainfall, and flash floods, have severely impacted the production of honey (see figure 8). These calamities have significantly disrupted the resources in the mangrove ecosystem, and honey production is no exception. As one honey seller stated:

> *"This year, honey production has been affected by floods, and the quality of honey has not been as good. Honey thrives in warm conditions, especially when exposed to sunlight." (Md. Selim, Honey Seller)*

Extreme weather conditions adversely affect the lives of honeybees, floral resources, and beehives, which are the primary components necessary for honey production. As a honey collector stated:

> *"The heavy rains have been a significant factor in this decline, as the rain damages the honeycombs and prevents the bees from finding food, resulting in a reduction in honey production." (Md. Ziaur Rhaman, Honey Collector)*

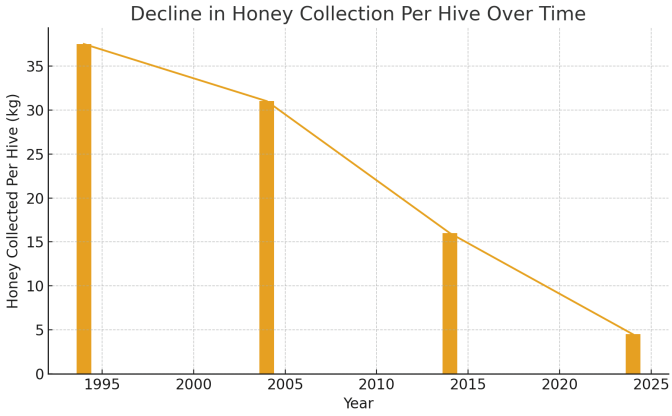

Figure 8: Decline in Honey Collection per Hive over Time (Source: Authors, through summarizing data from the respondents)

4.5.1. Impact on the lives of honeybees

Many collectors in the mangrove region harvest the hives before they are fully capped, and many do not use proper methods when cutting the hives. These practices, combined with excessive heat, result in the death of honeybees and larvae. As a honey collector expressed:

> *"The premature harvesting discourages bees from nesting in those areas again. Honey thrives in the summer, but extreme heat can cause many young bees to die, which in turn reduces honey production." (Md. Rezvi, Honey Collector)*

Using the proper method for cutting a hive and collecting honey is crucial to ensuring the honeybees feel safe and remain intact and alive. As a harvester stated:

> *"If the harvesting process is not done properly, many bee larvae die, which means there will be less honey in that hive the next time. If the hive is cut correctly, the larvae will survive. However, as the forest continues to shrink, the number of honey hives is also decreasing." (Md. Rezaul Karim Biplu, Honey Collector)*

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4.5.2. Lack of floral resources

Floral resources are the most crucial element in honey production. Flowers are the sole source of pollen from which honey can be made. But these floral resources in mangrove ecosystems are diminishing due to factors such as rainfall and flooding. As one honey seller asserts:

> *"Seasonal shifts have disrupted the blooming of plants, resulting in a decline in honey quality. While honey is typically better during the summer, excessive rainfall reduces both its production and flavor." (Md. Shuvo, Honey Seller)*

Deforestation has resulted in the extensive destruction of broad forest areas in the regions of Mirsharai and Sitakundo. This, in turn, has led to a significant reduction in floral resources in these areas. As one honey seller remarked:

> *"In Mirsarai, since the establishment of the industrial zone, many forests and gardens have been cleared, reducing the number of flowers available for bees. As a result, honey production has declined." (Md. Selim, Honey Seller)*

During periods of heavy rainfall, flowers are unable to grow properly, and pollen is washed away. Consequently, honeybees are not attracted to the flowers, which ultimately leads to a decline in both the quality and quantity of honey. As one disheartened honey collector expressed:

> *"There is no honey in winter, but honey production is best in summer, especially when the flowers from all the trees are in bloom. The weather also has a direct impact on honey production because honey is closely connected to flowers. If the weather is bad, the flowers won't bloom properly, which in turn affects both the quality and quantity of honey." (Md. Rezaul Karim Biplu, Honey Collector)*

Sunny weather is beneficial for the growth of flowers. Under such conditions, flowers are able to bloom properly, and with the appropriate warmth, the quality of the honey also improves. As one harvester explained:

> *"Sunny weather produces better flowers, and as a result, better honey. Honey thrives in the heat, as it is dependent on flowers, and the more sunshine, the better the quality of the honey." (Md. Nurul Haque, Honey Collector)*

4.5.3. Deforestation

Deforestation is one of the primary causes of the decline in both the quantity and quality of bitter honey. Just a few years ago, premium-quality honey was being produced in the mangroves of Mirsharai and Sitakundo. But in recent years, due to the creation of industrial zones, most forested areas have been cleared, resulting in a decline in the quality of bitter honey. This Deforestation has led to numerous issues in the region, many of which are directly connected to climate change. As one honey collector stated:

> *"A few years ago, the mangrove forest in this area produced excellent honey. However, with the ongoing Deforestation to make way for industrial zones, many trees have been cut down, and fewer flowers are blooming in those areas, resulting in a decrease in honey production." (Md. Rezvi, Honey Collector)*

The industrial zone is set to be further expanded into the forested area, resulting in increased Deforestation and leaving no forest remaining in that region. The activities for this expansion are already underway. As a consequence, the quantity and quality of honey will decline even further, and new climate-related issues will emerge. The weather will become more extreme, and, over time, the climate will inevitably change. As one honey collector affirmed:

> *"If the forest is destroyed, it will decrease further. Many forests are currently being cut down to make way for industrial zones, and many trees are being removed. The industrial zone will continue to expand, and it is expected to eventually reach our area as well. A road is being built right now, and in the next phase, it will be extended by another 5 kilometers. At that point, it will no longer be a forest." (Md. Rezaul Karim Biplu, Honey Collector)*

4.5.4. Excessive heat

A warm environment is beneficial for honey production. However, excessive heat can sometimes result in a decline in honey quality and even cause the death of honeybees. As one seller noted:

> *"Honey, in its pure form, does not spoil even if stored for years, and exposure to sunlight preserves its quality. However, due to both weather changes and adulteration, honey quality is on the decline." (Md. Shuvo, Honey Seller)*

However, in most cases, the morning heat is beneficial for honey production. From 9 am to the following two hours, honey yields are at their highest in warm weather. According to a harvester:

> *"Honey is at its best when it gets sunlight from 9 am onward; the heat during those next two hours is crucial for better quality honey. Afternoon heat, however, does not contribute to honey production." (Md. Akbor Hosen, Honey Collector)*

This suggests that while moderate morning heat benefits honey production, excessive afternoon temperatures damage hives and harm bee populations. There appears to be an optimal temperature range, with benefits below this threshold and harms above it.

4.5.5. Excess rainfall

Rainfall is one of the most impactful factors in climate change, contributing to reduced honey production. Rain not only washes honey away from the hive but also prevents honeybees from leaving it. During this period, honey production comes to a complete halt, and any honey that has been collected is washed away. As both a seller and a honey collector stated:

> *"Weather conditions also negatively impact honey production. For instance, rain prevents honey from being attached to the combs, leading to a reduced harvest. During rainy periods, bees tend to hide and are unable to gather nectar, resulting in honey being washed away." (Md. Selim, Honey Seller)*

> *"Even a single drop of water can cause the honey to flow out, leading to a reduction in the quantity of honey. Honey and water should never mix. Sometimes, if there are many bees, they shield the hive from water, but if the bees are absent, the honey is lost when rainwater enters the hive." (Md. Nurul Haque, Honey Collector)*

During heavy rainfall, honeybees are unable to leave the hive, forcing them to consume the honey stored within the hive in order to survive. This leads to a decrease in honey production as both the stored honey is consumed and new honey cannot be produced. As one honey harvester said:

> *"Rain significantly impacts honey production. When it rains heavily, bees cannot go out to gather nectar. If they cannot go out, they resort to consuming the stored honey within the hive." (Md. Islam, Honey Collector)*

Due to the rain, honey production has gradually decreased. Collectors now tend to harvest less honey than they did a few years ago. Rainfall can be somewhat destructive to honey collection, negatively impacting both yield and the process. According to a collector:

> *"I no longer collect as much honey as I used to; the quantity has decreased significantly. One of the main reasons for this is the rain. When there is heavy rainfall, bees do not return to their hives, resulting in less honey production." (Md. Rezaul Karim Biplu, Honey Collector)*

4.5.6. Flash floods and excessive flooding

Floods also have a detrimental effect on both honey production and quality. During floods, bees are unable to leave the hive, and in some cases, the flowers and hives themselves are destroyed, leading to a scarcity of food. Consequently, floods are not only harmful to people but also to honeybees, as well as to the production and quality of honey. As one seller expressed:

> *"Floods also damage the flowers, causing them to fall prematurely, which deprives bees of their food source, further reducing honey production." (Md. Selim, Honey Seller)*

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Floods not only destroy floral resources during the event itself, but also result in the permanent loss of many flowers. Consequently, even after the floodwaters recede, honeybees are unable to gather nectar due to the scarcity of flowers. As one harvester aptly posits:

> *"Rain and floods cause flowers to fall prematurely, and without flowers, no honey can be produced. Floods also destroy many bee nests, so both rain and flooding are detrimental to honey production." (Md. Rezvi, Honey Collector)*

4.5.7. Premature harvesting

The quality of bitter honey has significantly declined due to the practice of early honey harvesting. People often engage in this practice to achieve greater commercial gain. Premature harvesting not only reduces the quality of the honey but also makes it thinner in consistency. According to a seller:

> *"We source honey from sweet flowers in the Sundarbans and Mirsarai, but lately, the quality of honey has been declining due to various factors. Early harvesting, before the honeycombs are fully capped, reduces both the quality and quantity of honey. As commercial honey traders increasingly harvest prematurely, the honey is not as thick or as pure as it should be." (Md. Shahin, Honey Seller)*

The quality has declined so significantly that it now requires more honey than before to produce one kilogram. The decrease in density has reached such an extent that this is the case. As a seller affirms:

> *"The honey is now thinner than it used to be, requiring more volume to produce one kilogram. As a result, many sellers resort to adulteration to thicken the honey." (Md. Shuvo, Honey Seller)*

The size of a honeycomb does not necessarily indicate higher honey production. A large honeycomb can also yield less honey. Experienced collectors, with several years of expertise, are able to estimate the amount of honey in a hive, while novice collectors often struggle to predict accurately and may end up harvesting from the wrong honeycombs. As one collector noted:

> *"Not all honeycombs produce the same quantity of honey; some yield 1 kg, others 2 kg, and some even 10 kg. Many people cannot estimate the honey yield, but those of us with years of experience can accurately predict how much honey a hive will produce." (Md. Islam, Honey Collector)*

4.6. Threat of extinction of bitter honey

Both the quality and quantity of bitter honey have been steadily declining over time. Five years ago, a single beehive produced 12-14 kilograms of bitter honey, but this has now decreased to just 2-3 kilograms per hive. As a result, there is an existential threat to the future availability of bitter honey. As one collector stated:

> *"I have been collecting honey for around 4-5 years now. In the past, we used to harvest 10 to 12 kg of honey from small nests, but now, even though the nests are larger, we struggle to collect more than 2-3 kg of honey." (Md. Mostofa, Honey Collector)*

Bitter honey is only available for a brief period each year. However, even during that short window, its quantity has been steadily decreasing. Also, the honey itself has become thinner in consistency compared to previous years. As the collector expressed:

> *"This type of bitter honey is only available for a short period each year, and its availability has been steadily decreasing.....The taste naturally varies from season to season, yet the honey is becoming thinner, and the overall quantity is decreasing. If this trend continues, bitter honey may not be available in the near future." (Md. Ziaur Rhaman, Honey Collector)*

Deforestation has further complicated the threat of bitter honey's extinction. The forest in the study area has been destroyed at an alarming rate to make way for an extensive industrial zone, which also poses a significant threat to the existence of bitter honey and all other varieties of honey. As the honey collectors stated:

> *"However, I think that honey production*

will decline even further in the future. As the forests and gardens continue to disappear, there will only be small amounts of honey left in the countryside." *(Md. Islam, Honey Collector)*

"If the trees remain healthy, and if they are not cut down, and the weather improves, honey production will continue in the future. Since I started collecting honey, the taste of the honey has remained largely the same, but the quality has decreased significantly, and the quantity is almost nonexistent now." *(Md. Akbor Hosen, Honey Collector)*

4.7. A way forward

The honey from the Mirsharai and Sitakundo areas remains superior in quality compared to that of other regions. However, its quality has declined from previous levels. Increased promotion and greater awareness about bitter honey could help preserve this unique delicacy from the risk of extinction. According to a seller:

"Although the honey we now collect is somewhat inferior compared to earlier harvests, we believe that with increased promotion, the demand for bitter honey will grow as more people become aware of its unique health benefits." *(Md. Shahin, Honey Seller)*

Premature honey harvesting leads to the death of honeybees, a decline in honey quality, and negatively impacts its flavor. Therefore, harvesting fully capped hives using proper methods can help avoid these issues. As one collector stated:

"We avoid breaking the hive when there is less honey because we know that after 7-8 days, the honey will improve. Many people today complain that they cannot find good hives, but this is often because new collectors break the hive too early, before the honey has matured." *(Md. Nurul Haque, Honey Collector)*

Moreover, reversing the process of Deforestation can contribute to safeguarding this unique delicacy from extinction. However, climate issues have severely impacted the production, quality, and flavor of bitter honey. Therefore, raising awareness among all stakeholders is essential in preventing this extinction of bitter honey.

5. Discussion

This study identified several climate-related factors that threaten bitter honey production. Bitter honey is an exquisite and unique product of Bangladesh, found in only a few places globally. But this delicacy is under serious threat of extinction, largely due to climate change-related issues. This study explores the threats of bitter honey's extinction and examines the overall impact of climate change on its production, quality, and quantity. Using a qualitative approach, 10 in-depth interviews were conducted with honey collectors and sellers through a semi-structured interview guide. The study identified several significant impacts of climate change on bitter honey.

The study found that bitter honey is primarily produced in August, sourced from the pollen of *Gewa*, *Neem*, Bitter Gourd, *Minjiri*, and *Koroi* trees. These trees produce bitter pollen, which imparts the distinctive bitterness to the honey. This honey is produced in a short time frame, and its production has been declining over time. The main reasons for this decline include excessive rainfall, flash floods, lack of floral resources and growth, the death of honeybees, premature cutting of hives, and Deforestation. Excessive rainfall was identified as the most detrimental factor. During heavy rainfall and floods, honey is washed away from honeycombs, and honeybees are unable to leave the hive to collect nectar. Excessive heat also leads to the death of honeybees and their larvae. Without adequate floral resources and growth, there are no alternative sources for honey production. These floral resources are severely affected by excessive rainfall, floods, and heat. All factors, except premature harvesting, are directly linked to climate change. These factors were also found to negatively impact the honey lives and honey production in previous literature (Conte & Navajas, 2008; Sangomla, 2024; Lanoix, 2021).

In past years, honey collectors were able to harvest up to 14 kg of bitter honey from a single hive, but this has now decreased to just 2-3 kg per hive. In addition to the decrease in quantity, the quality of bitter honey has also declined. It now requires more honey to produce 1 kg of bitter honey, and its density and thickness have been compromised

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due to climate-driven factors. All honey collectors interviewed agreed that in the near future, the production, quality, and quantity of bitter honey will decline even further. So, the bitter honey is in serious threat of extinction in the near future.

Moreover, extensive Deforestation is underway to establish an industrial zone in Mirsharai, which has already led to the destruction of nearly half of the mangrove forest, with the remainder at risk. This Deforestation results in fewer floral resources and reduced honeybee habitats, and ultimately less honey production. It is crucial to raise awareness among the public, government, and all stakeholders to prevent the ongoing destruction of these forested areas for industrial development. This issue not only threatens honey production but also endangers the entire ecosystem. A comprehensive preventive policy is urgently needed to protect the unique bitter honey and the broader ecosystem of the mangrove forest area in Chattogram. The reviewed literature also addresses these issues, and several honey variants are similarly threatened with extinction worldwide (Neumann & Straub, 2023; Lanoix, 2021; Quinlan et al., 2023; Landaverde et al., 2023).

The limitations of this study include a small sample size, a lack of quantitative data, a lack of existing national and international literature on bitter honey, and no lab experiments. There are only ten (10) people found who actually have knowledge about bitter honey at the Chattogram mangrove forest. Additionally, no study has found single quantitative or experimental insights regarding bitter honey.

6. Conclusion & Recommendations

The production of bitter honey is currently facing severe threats due to recent extreme weather events, such as heavy rainfall and flash floods in the Chattogram area, which have severely impacted its production, quality, and taste. Compounding this issue, extensive Deforestation is taking place in the region, particularly in the mangrove areas of Mirsharai and Sitakundo, which are likely to be destroyed entirely if this continues. Over the years, both the production and quality of bitter honey have declined significantly. This year, the production has dropped to such an extent that honey harvesters and sellers are predicting heavy losses in the near future. Immediate attention is required to safeguard not only the honey but also the surrounding ecosystem.

This study has identified key recommendations to address these pressing issues, particularly in relation to climate change and the protection of bitter honey. The core recommendations are as follows:

- Establish protected zones within the mangrove forest that explicitly prohibit industrial development and designate enforcement mechanisms and penalties for illegal Deforestation. Partner with local communities as stewards of protected areas.
- Implement local and regional climate adaptation measures, including: (1) reforestation of degraded mangrove areas, (2) promotion of drought-resistant tree species that support honeybee forage, (3) wetland restoration to reduce flooding impacts, and (4) support for honey collector adaptation strategies, such as early warning systems and alternative income sources.
- Establish honey collector cooperatives or associations to: (1) regulate harvest timing to prevent premature harvesting, (2) establish shared sustainability guidelines, (3) provide collective marketing for bitter honey, and (4) create income stabilization mechanisms.
- Reconsider the proposal for an industrial zone in the mangrove forest area to avoid further exacerbation of climate-related problems.
- Raise awareness among all stakeholders, including local residents, project officials, government entities, and policymakers, to prevent the further decline of bitter honey production.
- Promote the uniqueness of bitter honey to encourage broader support for its preservation.

In addition, mitigating climate-related challenges should be a top priority. While addressing all the issues will be difficult, collaboration among all stakeholders, including government, local harvesting communities, and non-governmental organizations (NGOs), combined with a comprehensive policy, could be effective in protecting bitter honey from extinction. It is also worth noting that no published research or work on bitter honey has been conducted in Bangladesh to date. Such research could raise awareness and

drive policy-level changes. Exploring these issues further may uncover additional ideas and solutions.

In summary, protecting unique delicacies like bitter honey requires collective effort to build a more climate-resilient community, which will ultimately help resolve many climate-related issues.

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Appendix 1: Semi-structured Interview Guide Impact of Climate Change on Bitter Honey in Chattogram Mangrove Forest Area: An Exploratory Study

(For Honey Collectors and Sellers)

Name: **Phone Number:** **Address:** _____

1. How many years have you been engaged in collecting (or selling) this honey?
2. Why is the bitter honey of the *Mirsarai* region different from other types of honey? What is the level of demand for this honey?
3. Why does this honey taste bitter? Are you aware of any unique nutritional properties of this honey?
4. Has the production, collection, taste, or thickness of this honey altered in some way compared to before? If so, in your opinion, what are the reasons behind this alteration?
5. To what extent of rainfall and heat (and for how many days) does the quality and quantity of this bitter honey remain good?
6. In the past, when you went out in the morning to collect honey throughout the day, how much honey would you usually get? Due to changes in temperature or rainfall patterns/ intensity, are you now getting less or more honey compared to before? If less, what do you think are the reasons?
7. Do you think the seasons of heat and rainfall are occurring at the usual times now? Has the climate (long-term weather pattern) of this region changed over the past 15-20 years compared to before?
8. Over the past few years, what types of changes (increase or decrease) have you noticed in the production and collection of honey?
9. In your opinion, is there any possibility that the production of this honey may further decline or that it may disappear in the future?
10. Do you think the decline in production and collection of bitter honey is in any way related to climate (long-term weather) change? If yes, how are they related?
11. According to you, what could be the possible solutions or ways to overcome this situation? What would be your advice?
12. Do you think there is a possibility that this bitter honey might disappear in the future? If so, what reasons do you see behind it? Do you have any suggestions for maintaining the taste or quantity of the honey?
13. You may share any additional comments, advice, or information you would like to add.

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